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Evaluating Urban Alternative Energy Technologies for the Borough of Merton

Ashley J. Mossa Lindeman
Worcester Polytechnic Institute

Danielle N. Birmingham
Worcester Polytechnic Institute

William Robinson Caruso
Worcester Polytechnic Institute

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Communicating options to policymakers and
non-technical audiences

An Interactive Qualifying Project submitted to the faculty of Worcester Polytechnic Institute
in partial fulfillment of the requirements for the Degree of Bachelor of Science

Submitted by:

William Caruso
Ashley Mossa
Danielle Sorenson

Sponsoring Agency:

London Borough of Merton

Submitted to:

Project Advisors:
Scott Jiusto
Rick Brown

Project Liaison:
Adrian Hewitt

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mertonenergy-d06@wpi.edu

Executive Summary

Project Context

Fossil fuel consumption has increased over the past century, becoming a primary source of energy for many countries around the world and accounting for over 85% of the global energy produced as shown in Figure 1 (EIA, 2006). In combination with a rise in energy demands, this dependence on fossil fuels is leading to high carbon emissions and a continuing rise in energy prices due to the depletion of fossil fuel reserves.

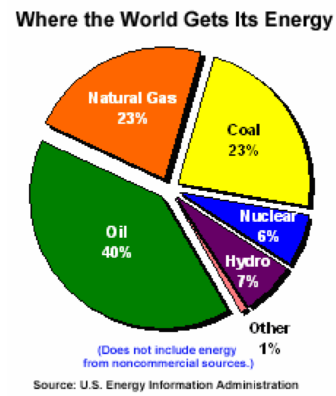

Figure 1: Global Energy Sources (ConocoPhillips, 2005)

International and national initiatives such as the Kyoto Protocol and the UK Renewables Obligation have been implemented to reduce carbon emissions by encouraging the use of more renewables and the implementation of alternative energy saving technologies. Unfortunately, these efforts have had little impact on the current state of energy consumption and carbon emissions in the UK, which are still above target levels as shown by the projected carbon emissions diagram in Figure 2. These problems are becoming particularly evident in London where carbon emissions are beginning to increase due to growing energy consumption and a projected increase in population by over 800,000 people by 2016 (Livingstone, 2004). As a result, the Mayor of London, Ken Livingstone, has proposed the Mayor's Energy Strategy, an attempt to focus initiatives on a local level in order to combat the problems associated with carbon emissions and energy consumption.

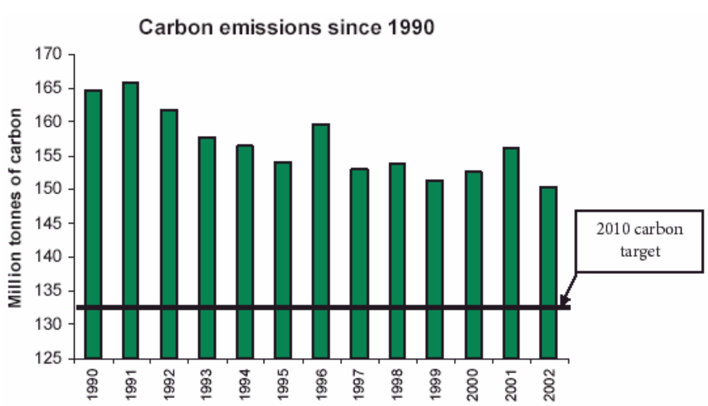

Figure 2: UK Carbon Emissions (Environmental Audit Committee, 2003)

Within the Mayor's Energy Strategy, the London Borough of Merton (LBM) has been recognized as one of four Energy Action Areas, a regeneration area in which elements of the Mayor's Energy Strategy will be simultaneously implemented within a single area in a replicable manner (London Borough of Merton [LBM], 2005). Under this strategy, LBM has focused their efforts in Mitcham, a small town in South East Merton, and has established a target of 20% carbon reduction by 2010 compared to 1990, and 60% reduction by 2050 compared to 2000 (Bowring, 2004). In order to achieve these goals, Merton has proposed a Carbon Reduction Strategy and the creation of a new energy infrastructure founded upon the implementation of a district heat and power (DHP) network powered by a system of combined heat and power (CHP) units and a range of renewable energy technologies and energy efficient systems (LBM, 2005). Merton intends to implement hydrogen fuel cells within the next 10-15 years, and is strongly considering the use of waste-to-energy technologies such as pyrolysis and anaerobic digestion within the next 5 years, both of which will simultaneously produce fuel for energy generation in CHP as well as reduce waste disposal in landfills, which is also a growing problem in Merton and greater London.

To realize this strategy, it is vital for key decision makers and planners in Merton to understand the available options. Engaging in productive discussion and creating a shared vision is the next step to move the borough forward in the developmental process. However, a problem which Merton faces today is a lack of effective communication tools that help planners prepare and politicians understand and share important aspects of the vision to make commitments for further development. Engineering and consulting firms have formulated detailed technical reports and feasibility studies on the possibility of implementing new, more efficient technologies. However, many of these reports do not communicate well to all audiences, including many policymakers who may not have a technical background or understanding. This creates a barrier between the possibility of implementing new technologies and actual implementation, which ultimately rests in the hands of policymakers in Merton council.

The purpose of our project was to bridge this communication gap by finding a way to explain the fundamentals of new alternative energy technologies, available units, and associated costs and benefits in an easy and clear way which all policymakers, planners and potential audiences could understand. Through extensive research we were able to gather enough information and knowledge to put together three potential educational resources and communication tools: an interactive guide, a hardcopy handout brochure and a technical reference report. Our guides were designed to tend to a range of audiences and learning styles and to cover all aspects of communication including visual presentation, internet accessibility, and literature.

Methods

Our tools would be primarily directed towards the city of Mitcham in the Borough of Merton, but would be designed in a replicable manner for other future Energy Action Areas. In order to create a final deliverable, our team conducted extensive research on various alternative technologies, identified the energy demands and power loads for Mitcham and evaluated and compared available equipment. A flowchart to visualize our methodology is shown in Figure 3.

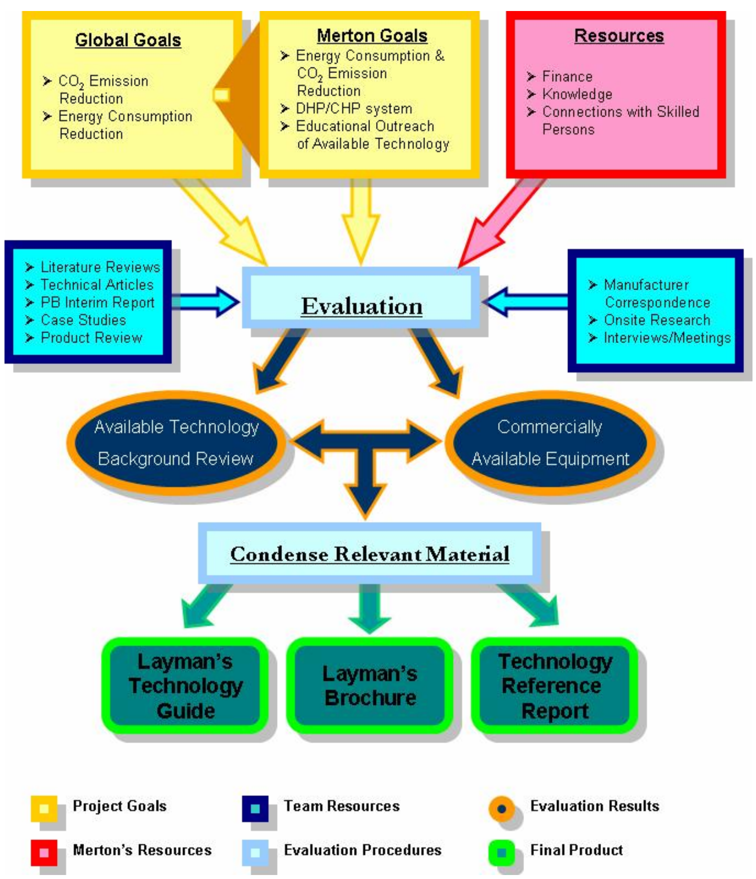

Figure 3: Methodology Flowchart

Researching Alternative Energy Technologies

Four main technologies were considered as possibilities for implementation: combined heat and power, hydrogen fuel cells, pyrolysis, and anaerobic digestion. Most of our research was completed during our initial preparation phase; however, additional research was conducted during our stay in London. Each technology was investigated with concentration on a variety of attributes including:

- Principle behind the technology
- Purpose

- How it functions
- Available types
- Advantages and disadvantages
    - Economic
    - Environmental
    - Availability
    - Reliability
    - Efficiency
    - Technological Maturity
- Case Studies

Our studies were based primarily on literature reviews, government reports, manufacturers' websites and various reliable internet sources.

Identifying Energy Demands in Mitcham

Before we could conduct specific research on available equipment and types of units, our initial objective was to identify the energy demands and relative power loads of high demand buildings within the Mitcham area, including municipal buildings, schools, and various other substantial energy users that might form a core for a DHP network. Because machines supply power based on energy demands, these figures would allow us to determine what size and range of CHP units would most efficiently satisfy Mitcham's energy needs. We were able to collect a number of actual and estimated annual heat and electricity demand figures, which we converted into average thermal and power loads for each building. Most of our data was based on a combination of sources, including an interim report from Parsons Brinkerhoff, a consulting company hired by Merton to conduct a feasibility study, and an energy audit which we obtained from another team of WPI students working for the Borough of Merton. Based on this information, we decided to focus our research on mid-sized CHP units, which would best fit the energy demand in Mitcham.

Evaluation and Comparison of Commercial Equipment

The most extensive portion of our work involved a general evaluation and comparison of available units for each of the four targeted technologies. In order to provide policymakers with actual figures and examples and gather additional research on each technology, we used literature reviews, case studies, manufacturer websites, and manufacturer contacts. We focused our evaluation on particular machine specifications which would be the most important elements in system planning including cost, size, land requirement, potential energy output, and in the case of pyrolysis and anaerobic digestion, waste capacity.

Information from both manufacturers and literature reviews was easily accessible for CHP units and hydrogen fuel cells due to the extensive commercial availability of CHP units and the growth in research for hydrogen fuel cells. We obtained specifications on a large number of available units for these technologies and created a supplementary database of CHP units in Microsoft Access to better organize this information and provide an additional tool for Merton policymakers. Such detailed information was not as easily available on the pyrolysis and anaerobic digestion waste-to-energy technologies, both of which are fairly new and immature technologies on a commercial scale. Much of the information we gathered regarding these technologies was general data based on a compilation of literature reviews and case studies, and for those companies which we did contact, only few responded or had equipment beyond a research level. Though detailed information on these technologies was difficult to obtain, enough information was collected for adequate knowledge about key specifications to provide meaningful communication about the technology.

Developing Communication Tools

The final stage of our project involved a compilation of all of our research into three communication guides. Our original intention for this project was to create a Layman's Guide which would communicate to and help educate policy makers on the technologies which Merton planned to implement in the future. The guide would include the fundamentals of CHP, hydrogen fuel cells, pyrolysis, and anaerobic digestion, the equipment available for commercial purchase, and the potential economic and environmental benefits and downfalls of these technologies on the Borough of Merton. Moreover, in order to comply with Merton's goals to establish themselves as a replicable model, the guide would be created such that it would be available to any of the neighboring boroughs, and more importantly, could be used by other future Energy Action Areas. However, in the process of creating our initial guide, we realized that such a product would be more replicable if it could be used by a number of different audiences beyond just policymakers or those people with a non-technical background.

As a final outcome for the Borough of Merton, our team created three different versions of an energy technology guide: an interactive guide, a hardcopy handout brochure and a technical reference report. The interactive guide is aimed at an audience with a wide range of background knowledge, as the reader is presented with a choice to view basic or detailed explanations. The handout brochure presents information on a basic level with each technology limited to one page. The technical report is aimed at the reader who desires more in depth explanations on the technology and provides a backdrop reference for the other two communication tools previously mentioned. All the tools are to be made available on Merton Council's website. We anticipate these tools to be the turning point in the decision of Merton council to begin implementation of a private wire network powered by CHP systems and possible other alternative technologies.

Abstract

To help reduce energy consumption and carbon emissions, the London Borough of Merton has proposed the implementation of cleaner, more efficient energy technologies. In order to inform policy makers of the carbon reducing options available to Merton, we have researched potential technologies and developed several communication devices: an interactive online guide, an informational brochure and a technical report. By educating Merton Council members, these communication tools will aid in the final decision to begin implementation of this equipment.

Authorship Page

The paper has been a collaborative effort between all group members. Each section has been written and revised by more than one person. However, each person specialized in the technologies that we have researched and the authorship of each deliverable as seen below. William contributed to the FATCAT database in collaboration with a second team of WPI students working with the Borough of Merton. Ashley did preliminary GIS Mapping and organized energy demands and loads. Danielle was our head researcher along with contributing greatly to the paper.

The Layman's Guide

Anaerobic digestion	Danielle Sorenson
Combined heat and power	Ashley Mossa
Hydrogen fuel cells	William Caruso
Pyrolysis	Ashley Mossa

Publisher Handouts

Anaerobic digestion	Danielle Sorenson
Combined heat and power	Ashley Mossa
Hydrogen fuel cells	William Caruso
Pyrolysis	Danielle Sorenson

Technical Report

Anaerobic digestion	Danielle Sorenson
Combined heat and power	Ashley Mossa
Hydrogen fuel cells	William Caruso
Pyrolysis	Danielle Sorenson

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Clarke-Energy
Ener-G
Compact Power
Organic Waste Systems
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The Sandwich Lady
The long tube ride to Morden

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Chapter 1: Introduction

Fossil fuel consumption has increased over the past century, becoming a primary source of energy for many countries around the world and accounting for over 85% of the global energy produced. However, as the demand for energy grows and dependence on fossil fuels increases, the problems associated with fossil fuel consumption are becoming more evident. The combustion of fossil fuels for energy production releases harmful emissions which are damaging our environment and contributing to global climate change. Moreover, the limited availability of fossil fuels due to their finite supply and the approach of a potential world production peak is causing a substantial rise in global energy prices as well as an urgent need for renewable and efficient energy systems.

There have been measures, such as the Kyoto Protocol and Renewables Obligation, which have been implemented on both an international and national level in an attempt to control greenhouse gas emissions by promoting the use of renewable energy and alternative technologies. Despite the measures implemented on this scale, the efforts are largely inadequate as the current trend of carbon emissions is still dramatically increasing. Carbon emissions are particularly high in London due to growing energy consumption in the densely populated area. From 1965 to 1999, energy consumption in London increased over 16% despite an overall 7% population decrease. With a projected population increase in Greater London by over 800,000 by 2016, problems are expected to worsen (Livingstone, 2004). As a result, Ken Livingstone, the Mayor of London, has proposed the Mayor's Energy Strategy.

Within the strategy, the Mayor has targeted the London Borough of Merton (LBM) as one of four energy action areas that will serve as replicable models for reduction in energy consumption and carbon emissions. Under the Mayor's Energy Strategy, LBM has a target of 20% carbon reduction by 2010 compared to 1990, and 60% reduction by 2050 compared to 2000 (Bowring, 2004).

As an Energy Action Area, Merton aims to meet its goals by experimenting with localizing energy production. "LBM proposes implementing a borough wide District Heat and Power (DHP) network driven by a series of combined heat and power (CHP) units augmented by a range of renewable energy technologies and energy efficient systems" (London Borough of Merton [LBM], 2005). One strategy that LBM is considering is the use of waste-to-energy technologies such as pyrolysis and anaerobic digestion that will simultaneously produce fuel for energy generation in CHP as well as reduce waste transport to landfills, which is an ever growing problem in Merton and greater London. To realize this strategy, it is vital for the key decision makers and planners to understand the available options. Engaging in productive discussion and creating a shared vision is the next step to move the borough forward in the developmental process.

There are numerous sources of information available relating to energy technologies including combined heat and power, pyrolysis, anaerobic digestion and hydrogen fuel cells. Manufacturers, engineering companies, and students have published a number of reports regarding how these technologies work, how much they cost, and the feasibility of their implementation on both a large and small scale. Engineering firms such as Element Energy and Parson's Brinkerhoff have already been working with LBM on feasibility studies for the implementation of a DHP network powered by CHP and other renewable technologies and the possibility of integrating energy networks to supply the Mitcham area.

Though the information currently available in technical reports provides an adequate and thorough understanding of each individual technology, the depth and detail of the research does not help planners prepare and politicians understand and share important aspects of the vision to make commitments for further development.

The purpose of our project was to bridge this communication gap by finding a way to explain the fundamentals of new alternative energy technologies, available units, and associated costs and benefits in an easy and clear way which all policymakers, planners and potential audiences could understand. Our project conveys the basic elements of available energy technologies via educational guides. Analysis of Mitcham's energy demands focused our research on the technologies that were best suited to fulfill the Borough's needs. We conducted extensive research on the fundamentals of waste-to-energy and combined heat and power generation technologies and gathered machine specifications from manufacturers and case studies to create an inventory of commercially available equipment. A compilation of our research will be available to LBM council members in a number of outcomes including an interactive presentation available online, a several page informational brochure and a detailed technical report. Our guides were designed to tend to a range of audiences and learning styles and to cover all aspects of communication including visual presentation, internet accessibility, and literature. The ideas and methods that form the foundation for our outcomes are based on general analysis and assessment which may serve as catalysts for other self-directed research and development in future Energy Action Areas.

Chapter 2: Background

The approaching energy crisis has forced both national and local governments to implement new sustainable energy projects. Many local governments, such as the London Borough of Merton, have proposed to cut energy consumption and lower carbon emissions through the use of renewable energy sources and the implementation of new alternative technologies. However, a lack of proper communication to policymakers of the fundamentals and benefits of these renewables has prevented such reductions from becoming a reality. This section will consider the existing global energy problems and the UK energy crisis, as well as discuss current initiatives being taken to reduce these problems in the UK; Merton's strategy to achieve their goals of reducing energy consumption and carbon emissions; and the importance of effective, easy to understand communication tools in the steps towards successful implementation of Merton's strategy.

2.1 Global Problem

Since 1979, the world has been increasing its production of petroleum exponentially and we are swiftly approaching an all-time peak in global oil production, which is forecast to occur sometime in 2006 (Duncan, 2000).The current production is more than 80 million barrels per day (BP Corporation, 2005). According to the Energy Information Association, crude oil productions accounted for nearly 40% of the globes energy sources in 2003. If energy production from coal and natural gas is included, over 85% of the total amount of energy produced is from fossil fuels. Approximately 13% of the energy produced is from nuclear and hydro-electric sources and less than 2% is from renewable sources (EIA, 2006).

Current global efforts are being implemented to reduce the carbon emissions and energy consumption, most notably the Kyoto Protocol. This measure was passed in 1997 under the authority of the United Nations. The overall objective of the Kyoto Protocol is to stabilize greenhouse gas emissions to prevent climate interference. Under this legislation, 160 industrialized nations that ratified the agreement in 1999 must employ measures for reductions in carbon dioxide and five other greenhouse gasses emission from 1990 levels by 2012 (EIA, 1998). The methods of reduction include, but are not limited to, enhancement of energy efficiency; research, promotion, development and increased use of renewable energy; and progressive reduction or phasing out of high energy consumption sectors (United Nations Framework Convention on Climate Change, 1997).

Despite the implementation of legislation including the Kyoto Protocol, the EIA world oil demand outlook expects consumption to rise from 80 million barrels a day to over 119 million barrels a day by 2025 shown by Figure 4 (EIA, 2005).

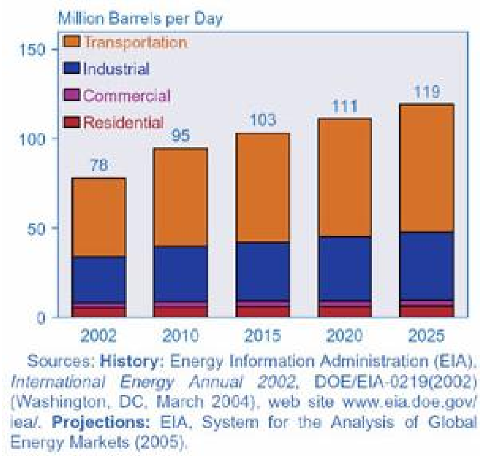

Figure 4: World Oil Demand in Barrels per Day, 2002-2025

The high rate of petroleum consumption creates enormous amounts of greenhouse gas emissions. In 2002 the global emissions of CO_2 from all fossil fuels (oil, gas and coal) was nearly 25 billion metric tons and is expected to increase to nearly 40 billion metric tons by 2025 as shown by Figure 5. In addition, petroleum is a finite source of energy; oil reserves are dwindling and continually more difficult to excavate (Kunstler, 2005). As petroleum production peak is met, the prices continue to rise, with the current average price for crude oil at over $65 per barrel (EIA, 2005).

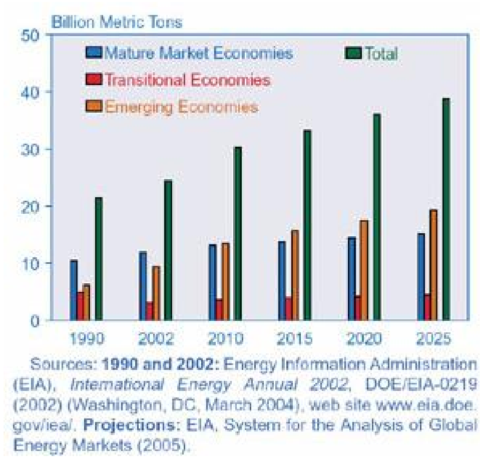

Figure 5: Global Carbon Dioxide Emissions in Billions of Metric Tons, 1990-2025

In light of the Kyoto Protocol, global energy consumption is still on the rise. To realistically understand and combat the problem, we will focus in on a more specific area. The following section discusses the same dilemma the world faces in a localized study of the UK and the reduction measures taken on a national level.

2.2 Energy Crisis in the United Kingdom

In recent years, the need for energy in the form of heat and electricity has begun to increase and exceed the capacity of fossil fuel energy reserves in response to the growing population and economy of the UK. Energy consumption is growing at an uncharacteristic rate, making the UK "one of the largest consumers in Europe" (EIA, 2005). Moreover, CO_2 emissions due to the burning of fossil fuels are a growing issue in the UK, contributing significantly to problems with climate change. Consequently, the UK is facing a number of problems that could eventually result in an energy crisis including growing government initiative to reduce CO_2 emissions, the depletion of North Sea oil and gas reserves, and a rise in electricity, gas, and oil prices.

2.2.1 $C0_2$ Emissions

Since the 1980s, UK government initiatives have placed growing importance on the reduction of carbon dioxide (CO_2) emissions in order to comply with European efforts to alter climate change. Recent studies have shown that the UK contributes approximately 2% to the world's CO_2 release, of which 95% comes directly from the burning of fossil fuels (Hetherington, 1996). Fossil fuel consumption is a growing trend in the UK, providing over 75% of the energy used in this European nation. However, in order to reduce CO_2 emissions, the UK government has begun to pass legislation enforcing the use of more efficient, less polluting alternative renewable energy sources in place of fossil fuels.

In 1989, the UK government issued the Electricity Act of 1989 in which they attempted to introduce renewable energies by imposing the "Non Fossil Fuel Obligation" (NFFO), an initiative that required utility companies to utilize specific quantities of non-fossil power from nuclear and renewable energy power plants (Altener Programme, 1998). Due to planning and implementation difficulties, the NFFO was replaced by additional legislation. In 2001, in compliance to the Kyoto Protocol in 1997 to reduce greenhouse gas emissions by 12.5% from 1990 levels, the British Government issued the Climate Change Levy of 2001 in which a tax was imposed on all industrial energy bills, including electricity, gas, coal, and liquid petroleum gas (LPG) (Wikimedia Foundation, Inc., 2006). The government hoped that an increase in energy tax would result in a corresponding better use of energy and incorporation of alternative renewable energy sources. In 2002, government promotion of renewable energy sources was further re-enforced by the Renewables Obligation (RO) under which electricity suppliers are required to generate a specific proportion of their electricity from renewable sources (DTI, 2005). Together, these initiatives have encouraged UK electricity suppliers to cut back on fossil fuel consumption and implement more energy efficient alternative sources and technologies in order to reduce CO_2 emissions, but have been largely inadequate.

2.2.2 Depletion of North Sea Oil and Gas Reserves

Gas is currently used as the primary energy source for heating and electricity in the UK, composing approximately 39% of the UK's primary energy supply (The Parliamentary Office of Science and Technology, 2004). Figure 6 shows the UK's primary energy demand in 2002 by fuel type.

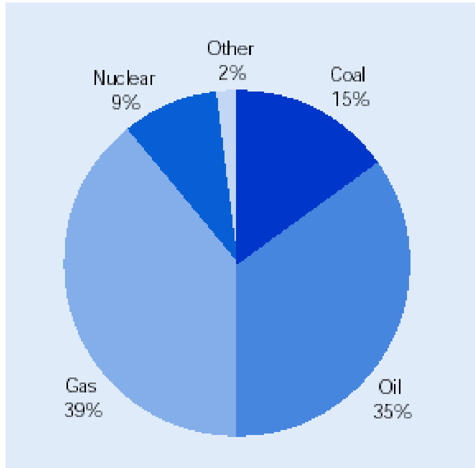

Figure 6: Primary Energy Demand in the UK in 2002
(Department of Trade and Industry, 2003)

The heavy reliance on gas for energy coupled with the growing demand for energy has begun to cause depletion of UK energy reserves, forcing the UK to import increasing amounts of gas and other fossil fuels. The consequences of this could be detrimental to the UK economy and the energy stability of both the UK and Europe.

2.2.3 Increase in Energy Costs

Since 2003, energy prices and wholesale gas prices have risen rapidly in the UK due a global rise in oil prices and the depletion of UK energy reserves (Figure 7).

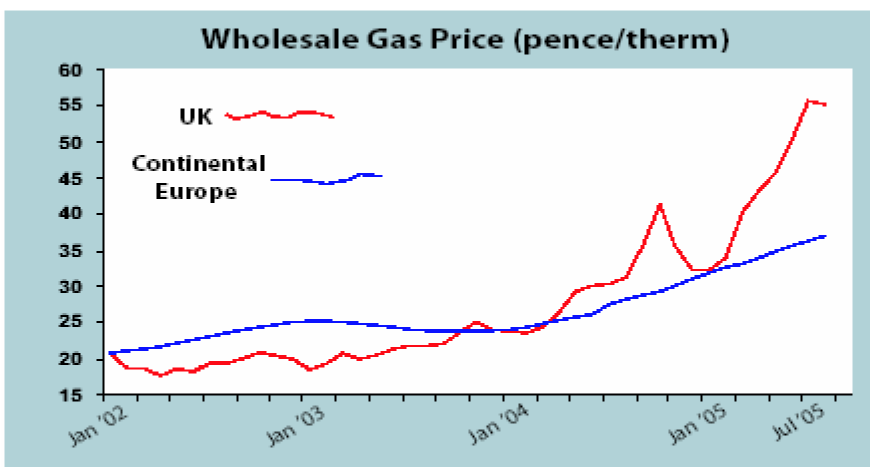

Figure 7: Wholesale gas prices in the UK and Europe since January 2002
(Energywatch, 2006)

Domestic gas and electricity bills have increased by 38% and 30% respectively. Many UK citizens are unable to afford these drastic price increases. In fact, nearly 200,000 households were pushed into fuel poverty between 2004 and 2005 (Energywatch, 2006). Moreover, industries are being forced to lay off workers or cut back production in order to reduce energy costs. In effect, the UK is experiencing a growing economic slowdown due to fossil fuel consumption.

2.2.4 The Future of Energy in the UK

Today, alternative energy sources and generation systems promise to provide for better energy efficiency, cheaper production and use, reduction in CO_2 emissions, and an abundance of resources. Locations like the London Borough of Merton stand at the forefront of implementing this energy technology.

2.3 Energy Action Areas

Though well intentioned, the measures implemented on the national and international scale alone are largely inadequate; carbon emissions and consumption are still on an upward slope. Actual achievements in reductions of both emissions and consumption "will require *real* changes" in energy use and supply (McEvoy, Gibbs, & Longhurst, 2000) While it is of acknowledged importance that this national and international action is necessary to facilitate reduction strategies, efforts on local and city scales can aid the national problem on several different levels (McEvoy et al, 2000). By implementing local measures, not only is the reduction of consumption apparent on both city and national levels, but the efforts are more palatable to people and can act as a positive example for other closely surrounding areas to follow.

This is the idea behind the action of Ken Livingstone, the Mayor of London. Ken Livingstone has targeted the borough of Merton as one of four Energy Action Areas that will serve as a "focal point for substantial reductions in energy consumption and corresponding carbon emissions" (Davis, 2005). Under this strategy, the mayor hopes to employ advanced technologies at a local level that will produce actual significant reductions in carbon emissions and energy consumption. The grand intention of the strategy is to create a "realistically replicable model for London boroughs and other high-density urban areas" (LBM, 2005)

Energy Action Areas (EAAs) are neighborhoods or regeneration areas in which elements of the Mayor's Energy Strategy will simultaneously be implemented in a single area (LBM, 2005). The goal of these urban environments is to reduce carbon emissions and introduce sustainable energy technologies and techniques in different types of buildings (Livingstone, 2004). Each EAA will be unique in design, but will be characterized by similar elements including the use of local heat distribution networks, small scale combined heat and power units, renewable technologies, and carbon reduction processes (LBM, 2005). The achievements made by these small-scale communities will provide models for greater London and a possible strategy for energy sustainability which can be replicated throughout London and Europe.

Energy Action Areas will demonstrate plans to comply with and exceed all current planning and guidance regarding energy use and sustainable implementation set forth by the London Plan (LBM, 2005). Within these plans, developers are required to apply the energy hierarchy described by Mayor Livingstone as "Be Lean, Be Green, Be Clean" (Livingstone, 2004). Under the hierarchy, EAAs must minimize energy demand, or 'be lean', through the incorporation of energy saving methods such as installing proper insulation to buildings. They will 'be green' by employing measures such that at least 15% of electricity produced must come from the use of renewable energy sources (Livingstone, 2004). Finally, EAAs must 'be clean' by supplying and delivering energy in an efficient manner using advanced technologies such as combined heat and power units coupled to district heat and power networks. EAAs are expected to demonstrate consideration to all activities that produce carbon emissions including transportation, waste and food (LBM, 2005).

2.4 Merton: Energy Action Area

The Borough of Merton was chosen as an Energy Action Area along with New Wembley, Barking Town Centre and Southwark with the aim of increasing the usage of renewable technology while increasing overall efficiency (London Sustainability Exchange, 2005). A press release in the London Sustainability Exchange quotes the Mayor of London, Ken Livingstone, stating that Energy Action Areas are aimed to get "together the people who can really drive forward a change in the energy we use in our homes and buildings – the developers, planners and finance sector" (2005). Although Merton is one of four Energy Action Areas, the Borough has devised a unique strategy to achieve the goals set forth by the Mayor's Energy Strategy and establish the Borough of Merton as a replicable model for greater London and other municipalities. The following section will highlight Merton's Energy Action Area strategy as well as the collection of organizations and businesses with whom Merton is closely working to achieve their proposed plan of action.

2.4.1 Merton's New Energy Infrastructure

Merton has focused their efforts as an Energy Action Area in Mitcham, a small town located in South East Merton. In order to meet and surpass the requirements of an Energy Action Area in Mitcham, LBM has devised a plan to reduce energy consumption and carbon emissions through the use of a localized energy network powered by a combination of renewable technologies and cleaner, more efficient energy generation systems. Merton intends to install combined heat and power (CHP) plants in specific areas throughout Mitcham which will be used to simultaneously generate heat and electricity. The heat, power, and possible cooling from these units will then be distributed to various buildings through a district heat and power (DHP) network. Initially, natural gas will be used to power these units. However, in the future, Merton plans to integrate alternative renewable technologies such as hydrogen fuel cells, wind turbines, and photovoltaic technologies to compliment these CHP systems.

2.4.2 Merton's Carbon Reduction Strategy

In addition to the CHP/DHP network, which are effective in carbon reduction strategies, Merton has created a further carbon reduction strategy which aims to reduce carbon emissions through such aspects as transport initiatives, a raise in community awareness, recycling, waste minimization, and more radical urban planning policies (LBM, 2005). Merton has particularly focused their efforts to reduce carbon emissions via waste minimization. The growing problems with waste disposal and landfill availability have encouraged Merton to consider alternative waste disposal methods which will not only help to reduce waste, but will produce usable energy as well as reducing carbon emissions.

2.4.2.1 Waste Minimization

Waste has become a growing issue in Merton and other boroughs in greater London over the past few years. As the population continues to increase throughout these regions, the amount of waste disposed of increases as well, resulting in decreased landfill availability and a rise in carbon emissions from waste left untreated.

As one of several local governments in greater London, LBM is responsible for both its own waste collection and its disposal (LBM, 2006). Merton has devised a number of strategies for waste disposal including an extensive recycling program which accounts for approximately 20% of

Merton waste, a composting facility, and landfilling, which is the most common form of municipal waste disposal in LBM.

In 2004/2005, approximately 100,231 tonnes of waste was collected by Merton council, 68% of which was biodegradable waste. This was a significant increase from the 98,076 tonnes of waste collected in 2000/2001. Of this amount, 83,301.14 tonnes of waste was disposed of in landfills, making up 83% of the total waste collected by Merton council (LBM, 2006). According to Cormac Stokes, the Principal Recycling Officer for the Borough of Merton, it currently costs £48 per tonne to dispose of such waste. However, due to the projected decrease in space availability in landfills, every tonne of waste over the permitted landfill limit will cost £200. Figure 8 provides a basic visual of future projections for waste disposal in landfills.

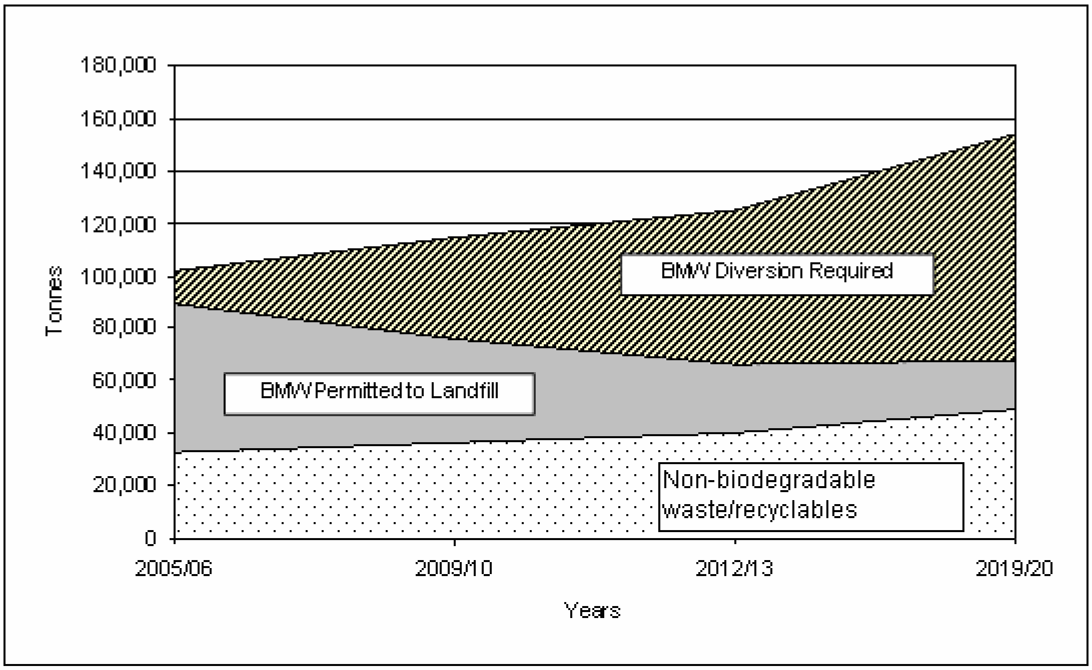

Figure 8: Landfill Waste Disposal Projections 2005-2020 (LBM, 2006)

According to Figure 8, Merton will need to divert 20,000-80,000 tonnes of waste over the next 10-15 years in order to avoid significant landfill costs and potential carbon emissions from untreated waste in landfills. To avoid these risks and further meet the goals of an Energy Action Area, Merton is exploring waste-to-energy technologies such as pyrolysis and anaerobic digestion which can convert biodegradable waste to potential sources of fuel for energy generation. These renewable technologies will not only help in the reduction of carbon emissions, but will minimize waste and generate potential alternative fuel sources for CHP systems.

2.4.3 Merton's Partners

The Borough of Merton is currently working in conjunction with many businesses, organizations and municipalities to adhere to the goals set forth by the Mayor's Energy Strategy. These partners are intended to span a wide range of disciplines to work toward a solution from finance, planning and legal aspects to waste services, street management and housing, to bio diversity, community consultation and communications (LBM, 2005). Some of LBM's external partners include:

- London Development Agency
- Climate Change Agency
- Energy for Sustainable Development

The efforts of these organizations are essential for the development of a solution to ultimately reduce energy consumption and carbon emissions in Merton and greater London. However, in order to combat the problem on a local level and begin plans for implementation of a new energy infrastructure, LBM is also working closely with several private businesses and organizations in the UK. The span of partners includes, but is not limited to:

- Local energy suppliers, manufacturers and installers
- Consulting organizations
- Government funding agencies
- Community awareness organizations

Many of these businesses and organizations have been hired by LBM to conduct studies and services that will provide Merton with the necessary information to begin implementation of an energy infrastructure powered by new alternative technologies. In particular, LBM has been working closely with such businesses as Parsons Brinkerhoff and Element Energy, consultancy and engineering companies which have been working separately to assess different aspects of the feasibility of a district heat and power network run by a combination of CHP units and various other complementary technologies. Much of the initial work and research provided by these two resources has been an important asset to the outcome of this project, adding further detail to our research and focusing our study on the most effective alternative technologies for significant reductions in energy consumption and carbon emissions.

2.5 Communication Barriers for Implementation Action in Merton

Although LBM has hired a number of companies and organizations to conduct feasibility studies and obtain current research on up and coming alternative technologies such as CHP, hydrogen fuel cells, pyrolysis, and anaerobic digestion, the depth and detailed technical level of these reports does not communicate well with every key decision maker in Merton who is responsible for successful implementation of a CHP/DHP network. In order for policymakers to initiate active implementation of such new and uncertain technologies, both audiences of a technical and non-technical background require a basic understanding of how each technology works, how much it costs, and the associated benefits and risks. There are numerous resources available online and in literature regarding these specific factors, but the time required to filter through such an excess of research is an unreasonable expectation for policymakers and LBM if they expect to achieve the goals outlined by the Mayor within the next few years. Thus, for successful implementation of a CHP/DHP network and other alternative renewable technologies to occur in Merton, policymakers will require effective, easy to understand communication tools that outline the fundamentals and benefits of each technology in a way such that every member of council will understand.

2.6 Breaking Through Communication Barriers

Successful communication to a wide range of audiences requires a two step process. The first step is finding available information sources which are reliable and the second is condensing the available information into a format which will hold the interest of a curious reader and convey information in a logical and comprehendible manner.

2.6.1 Available Information

There is a significant amount of information from a number of reliable sources on the energy topics discussed in this report. However, quite often one information source may not be adequate or may have too much information for the non-technical reader. Furthermore, the necessary information may not be available from public domain sources. The maturity of the technology is a major determining factor in the availability of information.

There are many reliable information sources readily available, especially on the internet, of which we relied upon three general types:

- Government websites
- Journal articles
- Manufacturer websites

Government websites such as the UK/US Department of Trade and Industry and the US Department of Energy provide reliable and readily accessible sources for concise background knowledge and the technology's developmental status. Government websites provide concise and quality backgrounds on technologies such as combined heat and power, fuel cells and renewable technologies like photovoltaics and wind turbines.

Journals provide specific and detailed background information as well as useful case studies. The information in these reports targets the audience with more technical aptitude. Information on many technologies can be found in journal articles, including CHP, fuel cells, pyrolysis and anaerobic digestion. Case studies are most useful for finding information on technologies such as pyrolysis and anaerobic digestion, as there are few dedicated manufacturing companies from which detailed information and specifications can be obtained.

Manufacturers' websites represent the best source for the latest development of the technology as well as detailed specifications on the capabilities of specific machines. However, manufacturers sometimes do not provide detailed background studies on the principal or general process by which the technology operates. In addition to the information provided by the website, directly contacting manufacturers is especially useful for gathering up-to-date information on mature technologies and can provide a wealth of information concerning price, maintenance issues, and installation issues.

2.7 Conclusion

With the steady increase in greenhouse gas emissions and energy consumption in the UK and worldwide, it is essential to reevaluate current methods of energy production. Recent legislation has deemed it necessary to move away from non-renewable sources and to experiment with renewable energy sources and more efficient energy production systems. Environmentally, economically and ethically it is important for the United Kingdom and London Borough of Merton to be frontiers in the reduction of energy, especially from renewable sources and technologies such as pyrolysis, anaerobic digestion, and hydrogen fuel cells. The Borough of Merton is taking steps in the right direction by proposing a district heat and power scheme run by combined heat and power systems which produce electricity and heat from one unit. Initiatives must now be taken in order to create replicable tools and models to communicate these ideas to Merton council members and successfully make Merton's strategy and the principles of an Energy Action Area a reality.

Chapter 3: Methodology

The fundamental goal of our project was to produce various communication tools for the London Borough of Merton to educate key Merton council members, planners, and decision makers on the alternative energy technologies and commercially available CHP units which they could potentially implement in Mitcham based on their Energy Action Area strategy. Due to the variation in educational and technical backgrounds of policy makers, our team created three different versions of an energy technology guide, each of which encompassed all of our technology research and the available equipment displayed in several levels of depth and detail, ranging from a brief handout on each technology to an in-depth technical report. In order to fulfill Merton's role as a replicable model for other future Energy Action Areas and greater London, we designed the guides as communication and educational tools which would not only provide a service to Mr. Adrian Hewitt and Merton Council, but to other planners, students, interested readers and any other neighboring boroughs.

Our project was conducted between March 13, 2006 and April 28, 2006. Our focus was the small niche which outside engineering firms could not provide Merton: an overview of relevant energy technologies in both a non-technical and technical format that could communicate to a variety of audiences.

The following set of objectives was essential for the success of our project:

- Determine energy needs for a CHP/DHP system in Mitcham
- Research and analyze relevant energy technology
- Evaluate and compare physical equipment for relevant technologies
- Compile research and package into energy technology guides

We were able to stay on task and achieve each of our objectives based on the timeline outlined in Figure 9.

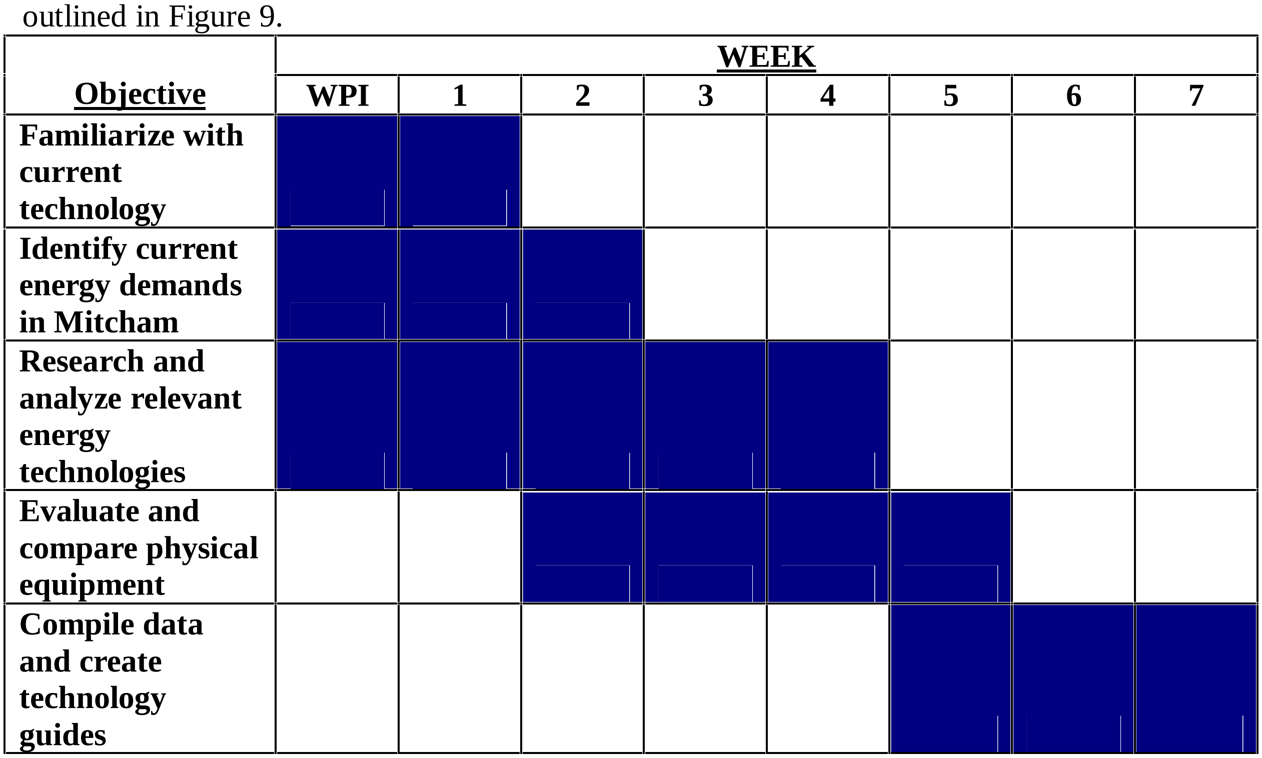

Figure 9: Project Timeline

In the long run we hope our guides will link the concepts of consultant's feasibility studies to policymakers, and that our findings will provide a viable foundation from which Merton Council will agree to move forward with the implementation of a DHP network run by a series of CHP units and fulfill their responsibilities as an Energy Action Area. A diagram of our overall project aims is shown in Figure 10.

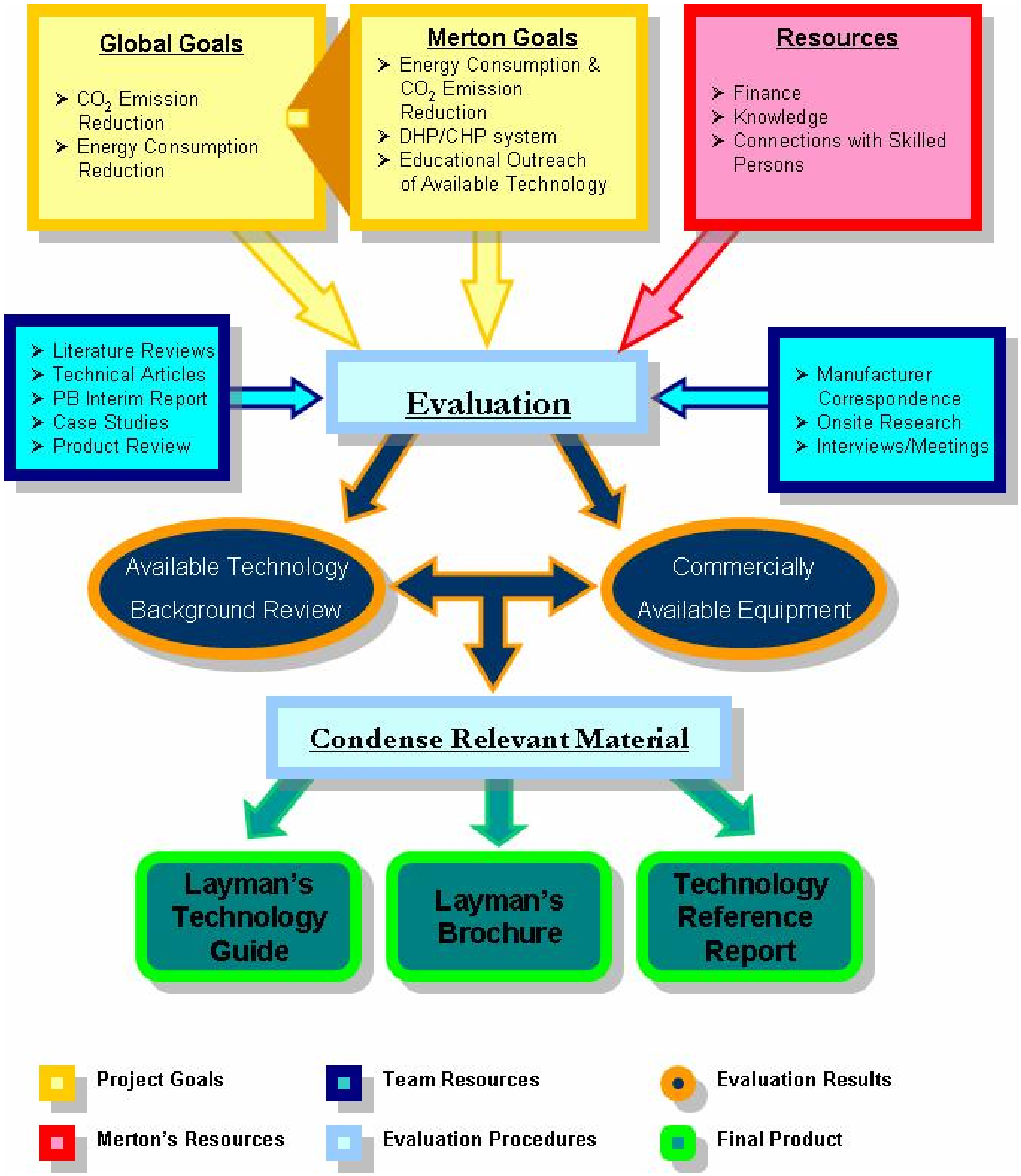

Figure 10: Overall Project Aims

3.1 Determine Energy Needs for a CHP/DHP System in Mitcham

The London Borough of Merton has focused their implementation of a DHP network powered by a series of CHP units in Mitcham, a small town located in South East Merton. The DHP network will include offices, schools, social residencies, a town hall, social services, and a leisure center (LBM, 2005). Space heating and hot water will initially be supplied to these areas by the DHP network with the possibility that electricity will eventually be transmitted and distributed to specific buildings using CHP units (Parsons Brinkerhoff, 2006).

LBM is currently still in the process of planning the DHP network and the specific placement of alternative technology. Much of the energy generation within the DHP network will be the result of a strategically implemented combination of CHP generation equipment and waste-to-energy technology. In order for our team to focus our research on the most appropriate technology and machinery for heat and power generation in Mitcham, it was important that we first determine specific energy needs for the Borough of Merton. In particular, we needed to identify the total energy demand and relative thermal and electrical load for each building that could potentially be incorporated into a DHP network in Mitcham. Although we devised replicable communication models which could potentially be used in other Energy Action Areas, our focus on energy demands enabled us to create some aspects of our communication tools which were specifically directed towards the needs of Merton.

The following section will explain the methods which we used to identify the energy demands and power loads for the buildings of South East Merton. It will discuss what information we needed as well as how we found and used it.

3.1.1 Identify Energy Demands and Power Loads for Mitcham

The total energy demand and power load for every building that could potentially be incorporated into a DHP network was first identified. Such data as average annual heat demand (kWh), average annual electricity demand (kWh), and average thermal and electrical load (kilowatts [kW]) for each building enabled us to specifically focus on those technologies and associated units which would most effectively and efficiently provide for the power requirements of Mitcham and other similar urban areas. Upon our arrival in London, we gathered data regarding energy demand from the following sources:

- Parsons Brinkerhoff's feasibility study for a district heat and power network in South East Merton
- A team of students from Worcester Polytechnic Institute working with the Geographic Information System (GIS) for the Borough of Merton

LBM has been working with Parsons Brinkerhoff (PB) over the past months in order to determine the feasibility of a district heat and power network in South East Merton. The final PB feasibility report was expected to be completed by the end of February, prior to our arrival in London. However, upon our arrival, the final PB report was still unavailable. Our only source of energy demand data was contained in the PB interim report released in January 2006 which contained preliminary research on the Mitcham area. In the interim report, PB included an initial assessment of the energy demands of those buildings which could possibly support a DHP network in Mitcham. PB focused on government owned buildings and other structures which had the potential for significant heat and/or electricity demands including schools, social housing, supermarkets, hospitals, community structures, and any future developments which had the potential for significant energy demand (Parsons Brinkerhoff, 2006).

The energy demands of each of these buildings was determined from a mix of data including annual energy use data from available public records, such as electricity and heating bills, and benchmarks where information was unavailable, in which PB estimated the energy demands for buildings based on the CIBSE guide. The CIBSE guide is a publication released by the Chartered Institution of Building Services Engineers, an internationally represented group of engineers that provides building related services. The guide supplies information on energy efficiency in buildings, including benchmark energy use figures for a range of structures (The Chartered Institution of Building Services Engineers, 2006). The benchmarks are based on building features, such as the size of the building, and are presented in kilowatt-hours/square meters. The accuracy of the information varies, but PB was able to estimate the energy demands for buildings in Mitcham by comparing them to the benchmark energy consumption figures for buildings of similar structure.

PB devised a list of the annual average heat and electricity demands for each building in kilowatt-hours (kWh), including actual and estimated figures. We collected all the data figures from this list relative to our own project needs including the identity of each individual building which could potentially be supplied by a CHP/DHP network, and the annual energy demands of each building in kilowatt-hours, including heat and electricity demand. Initially, we had planned to base our research and the sizing of equipment based solely on such electricity and heat demands. However, we realized that electricity and heat demands are specified in kilowatt- hours, which is a unit of energy, and manufacturers typically base the sizing of CHP equipment on kilowatts, which is a measure of power. Thus, we needed to consider electricity and heat demands in terms of thermal and electrical loads for each building in order to determine which machines could potentially satisfy Mitcham's energy needs. To do so, we converted the energy demands we collected from the PB report to average heat and electrical loads in kilowatts for every building based on the following conversions:

$$\text{Power Load (kW)} = \frac{\text{Energy Demand (kWh)}}{\text{Time (h)}}$$

$$\text{Average Annual Power Load (kW)} = \frac{\text{Average Annual Energy Demand (kWh)}}{\text{Number of Hours in a Year (8760 hours)}}$$

Each figure was individually divided by 8760 hours. The resulting loads were significantly lower than the energy demands and appeared much more reasonable in comparison to the equipment specifications outlined by manufacturer websites.

In addition to Parsons Brinkerhoff's efforts, LBM is also working closely with another team of students from Worcester Polytechnic Institute (WPI) to gather data on building energy consumption and carbon emissions for the Borough of Merton's Geographic Information System (GIS). A GIS is a computer technology which can be used to map specific data in order to solve problems, manage data, or study trends over time (Environmental Systems Research Institute, Inc., 2006). In an effort to map current carbon emissions in Mitcham and update Merton's GIS, these students developed a plan to gather the energy consumption figures for each building in the Mitcham area based on actual meter readings, energy bills, and estimated benchmark figures. Their research took all of the Mitcham area into account, but focused primarily on the energy consumption of those buildings with the most significant heat and electricity demands, such as municipal buildings. As we expected, much of their data complemented the PB report, adding information which was not included or based solely on estimations. We collected data regarding heat and electricity demand in kilowatt-hours for each building which Merton deemed should be included in a DHP network and/or which we believed could be supported by CHP systems in a DHP network. Most of the data we received was in terms of average annual heat and/or energy demands. We converted these figures into average power loads for each building based on the previous conversion factor. Although we did not have monthly or seasonal energy demand figures which we could use to properly size a machine, we were able to focus our research on a range of machines centered primarily around these energy demands.

The information gathered from Parson's Brinkerhoff and LBM's Geographic Information System was recorded and outlined in the table shown in Table 1.

Energy Demands and Power Loads for Mitcham					
Building Name & Description	Heat Demand (kWh)	Electricity Demand (kWh)	Heat Load (kW)	Electricity Load (kW)	Future Development (Y/N)

Table 1: Energy Demand for South East Merton

The table included specific building name and description, heat demand (kWh), electricity demand (kWh), heat load (kW) and electrical load (kW) for each building. An additional column indicating the building as a future development with the potential for significant energy demand was included at the end of the table so that we could take any proposed buildings into consideration when determining the total energy demand for Mitcham in the future. Because some of the estimated data from the PB report and GIS project was contradictory, some of our energy demands were recorded based on the most reliable source of benchmark data. However, none of the figures were altered for those demands for which we had actual energy data. Necessary conversions were made so that all of our energy demand figures were recorded in kilowatt-hours and all of our power load figures were recorded in kilowatts.

Building upon the research of Parsons Brinkerhoff and WPI, we were able to convert and interpret all of their data for our specific project needs. In particular, we established a foundation for our technology research and equipment evaluations based on the energy needs and power loads of South East Merton, which could be comparable to additional urban environments. In addition, we were able to determine the power output required by a potential CHP unit or alternative energy technology system based on the buildings being supplied.

3.2 Explore Alternative Fuel Production and Generation Technologies

According to information contained in the Merton Energy Action Area Proposal (2005), Merton intends to produce 10% of its energy needs from renewable sources by the year 2015. Merton already has plans to implement a district heat and power scheme powered by combined heat and power units, but also hopes to implement additional technologies in the future including hydrogen fuel cells, pyrolysis, and anaerobic digestion. In order to focus our Layman's guides on the most relevant technologies applicable to Merton and other potential boroughs in the UK, our team conducted in-depth research on the following key technologies:

- District heat and power networks
- Combined heat and power units
- Hydrogen fuel cells
- Pyrolysis
- Anaerobic digestion

We looked specifically at the general processes of each as well the available types, uses, and potential advantages and disadvantages including environmentally and economically. Most of our research was conducted during the preparation phase prior to our arrival in London. However, during the project timeframe, we did have to elaborate on some important aspects of our current background research for the purposes of our Layman's guide and the various alternative versions. Figure 11 shows the procedure which we used to approach our technology research and organize the information into a logical guide or report.

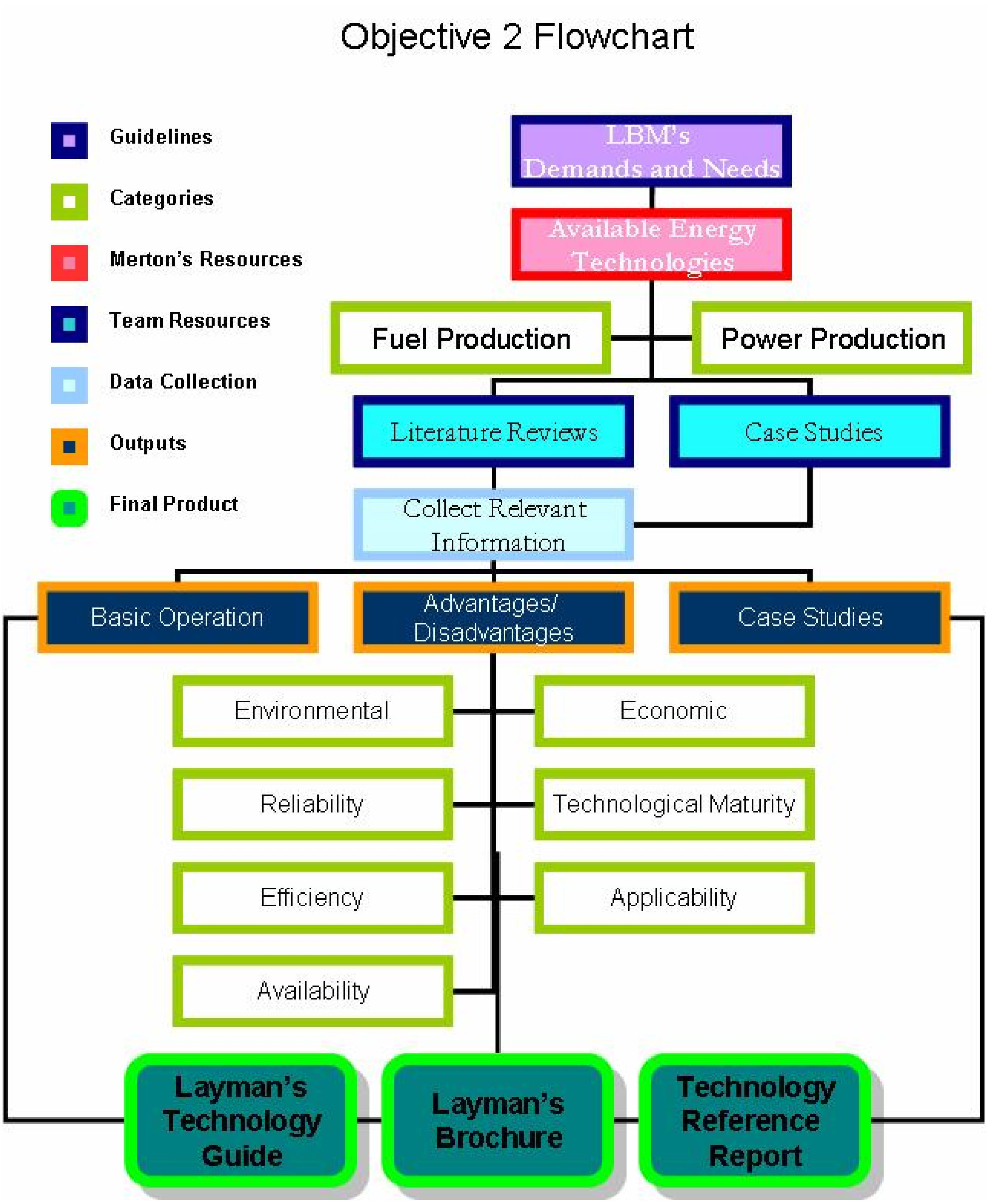

Figure 11: Procedure Flowchart for the Research of Alternative Energy Technologies

3.3 Evaluate and Compare Available Equipment

The next step taken for a greater understanding of the current energy technologies available was to investigate current commercially available equipment. For the purposes of this project, our main focus was on several different types of combined heat and power production technologies and various types of waste-to-energy units. For CHP production, we considered natural gas powered units as well as hydrogen fuel cells. For waste-to-energy technologies, we investigated anaerobic digestion and pyrolysis units in detail. The evaluations were conducted keeping in mind the specific needs set forth by the Borough of Merton and previous objectives. Figure 12 contains a general flow chart illustrating our evaluation procedure as well as the general criteria which we thought was most crucial.

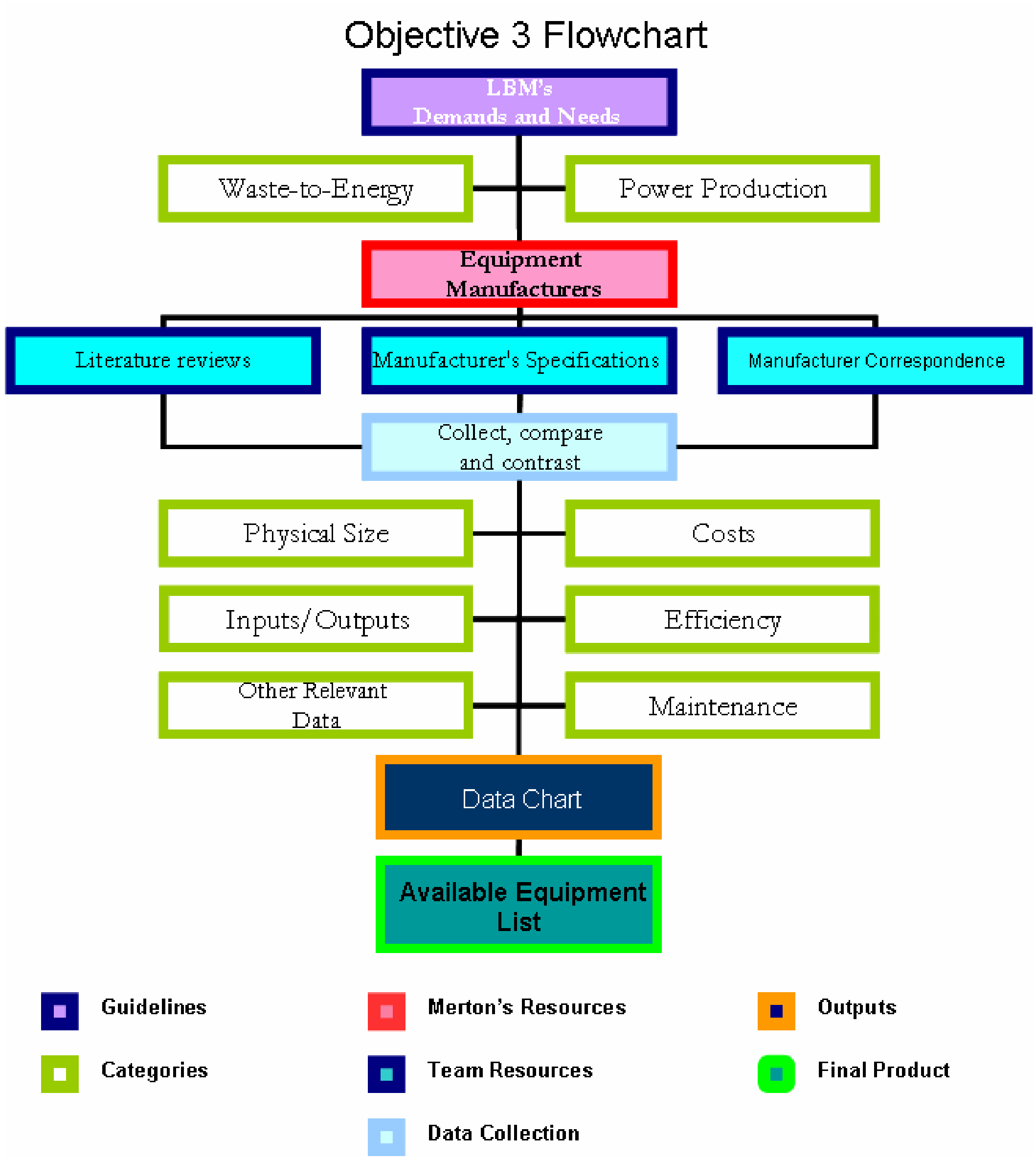

Figure 12: Procedural Flowchart for the Evaluation and Comparison of Available Equipment

Since we evaluated both power production and waste-to-energy technologies, two slightly different methodologies for evaluation were used and are discussed separately in the following sections.

3.3.1 Evaluate CHP Production Equipment

The procedure for the evaluation of CHP production equipment addressed all issues set forth in the flowchart. The CHP generation evaluation procedure was specific in terms of the data that must be collected for power production. Since there are a variety of technologies currently available, we first compared some key aspects of power generation technologies with respect to the different types of technologies available. We based our comparison on the spreadsheet shown in Table 2 which included specifications for currently available CHP technologies.

Typical Cost and Performance Characteristics by CHP Technology						
Technology	***Steam Turbine***	***Diesel Engine***	***Natural Gas Engine***	***Gas Turbine***	***Microturbine***	***Fuel Cell***
Electrical Efficiency (approx.)	15-38%	27-45%	22-40%	22-36%	18-27%	30-63%
Overall Efficiency (approx.)	80%	70-80%	70-80%	70-75%	65-75%	65-80%
Typical Capacity (kWe)	0.2-800 Mwe	30-5000	50-5000	1-500 MWe	30-350	10-2000.
Power to Heat Ratio	0.1-0.3	0.5-1	0.5-1	0.5-2	0.4-0.7	1-2.
Part Load	ok	good	ok	poor	ok	good
CHP Installed Costs ($/kWe)	300-900	900-1,500	900-1,500	800-1,800	1,300-2,500	2,700-5,300
O&M Costs ($/kWe)	<0.004	0.005-0.015	0.007-0.02	0.003-0.0096	0.01 (projected)	0.005-0.04
Availability	near 100%	90-95%	92-97%	90-98%	90-98%	>95%
Hours to Overhauls	>50,000	25,000-30,000	24,000-60,000	30,000-50,000	5,000-40,000	10,000-40,000
Start-up Time	1 hr - 1 day	10 sec	10 sec	10 min - 1 hr	60 sec	3 hrs - 2 days
Fuel Pressure (psi)	n/a	<5	1-45.	120-500 (compressor)	40-100 (compressor)	0.5-45
Fuels	any	diesel, residual oil	natural gas, biogas, propane, landfill gas	natural gas, biogas, propane, oil	natural gas, biogas, propane, oil	hydrogen, natural gas, propane, methanol
Noise	high	high	high	moderate	moderate	low
Uses for thermal Output	LP-HP steam	hot water, LP steam	hot water, LP steam	heat, hot water, LP-HP steam	heat, hot water, LP-HP steam	hot water, LP-HP, steam
Power Density (kW/m^2)	>100	35-50	35-50	20-500	5-70.	5-20.

Table 2: CHP Machine Technology Summary
(U.S. Environmental Protection Agency [EPA], n.d.)

We used the general format outlined by Table 2 to conduct our own evaluation of CHP technology.

In order to focus our efforts, we discussed which technologies were realistic for actual implementation with our liaison, Mr. Adrian Hewitt, based on those technologies included in Table 2. It was discovered upon researching several cases that gas reciprocating engines are the most realistic for immediate results. However, for a long-term high-tech option, we researched fuel cell options in detail. Fuel cells would serve as a high-tech comparison against the mature and proven gas piston engine technology.

Our decision to focus on reciprocating engines was based on the fact that gas engines are:

- A proven and reliable technology
    - Hundreds of CHP systems in use
    - Relatively inexpensive
- Versatile
    - Can be used with many fuels
    - Wide range of sizes
- Available
    - Many manufacturers
    - Spare parts readily available
- Efficient – over 85% in many cogeneration cases
- Fit the size demands of Merton

After focusing our research efforts on gas piston engines and fuel cells, we then were able to seek manufacturers and installation companies. Using the UK CHPA website (http://www.chpa.org/), we compiled a list of manufacturers and contact information, an example of which is shown in Figure 13. The full chart can be found in Appendix A. We used this chart as a guideline and checklist for organizing our research of manufacturers.

Manufacturer Contacts							
Company	Technology	Contactee	Email	Phone	Time	Location	Website
ABB CHP Limited	CHP	terry coldwell sandy honeyman	terry.coldwell@gb.abb.com sandy.honeyman@gb.abb.com	01785 825 964	0900-1700	Staffordshire	www.abb.com
Aircogen CHP Solutions	CHP	Joe Knowles	Joe.Knowles@aircogen.co.uk	44 (0) 1733 292 450		Peterborough, Cambs	www.aircogen.co.uk

Figure 13: Owner and Manufacturer Contact Spreadsheet

The next step was to seek the necessary information on each piece of equipment. This was done through a combination of online research of company websites and phone contact. During the online research process, we found several companies who specialized in turn-key CHP applications, which became the primary focus of our research.

Once we had focused our efforts to turn-key applications, we found six companies that specialized in mid-sized CHP distribution and installation including Aircogen, Clarke-Energy, Cogenco, Ener-G, Xergi, and E on UK. We determined that mid-sized CHP was the most viable option based on the energy demands of the Mitcham area.

Many of the necessary machine specifications were found on company websites; however it was still necessary to directly contact some manufacturers for the price of the equipment as it is not often found on public domain websites. Manufacturers were contacted and asked a variety of questions based on the information we needed. We did not use a specific list of questions as a reference, but rather, asked on the spot inquiries based on our previous criteria and what information was unavailable on company websites and necessary for our research.

In addition to manufacturer's websites and telephone interviews, we researched case studies of installed CHP systems. From these case studies we were able to gather basic information regarding the reliability of the machines, carbon savings and actual data regarding efficiencies and costs. Furthermore, the case studies provided us with knowledge about the process used for the implementation of a CHP system.

All data researched was compiled and organized into data spreadsheets, such as that shown in Table 3.

Reciprocating Engine CHP Comparison		
Company	*Cogenco*	*Cogenco*
Model	CGC-0082-L-NGUK-50	CGC-0130-L-NGUK-51
Type	Gas Engine	Gas Engine
Engine Manufacturer		M.A.N.
Electrical Power (KW)	82	130
Thermal Power (KW)	132	201
Electrical Efficiency	33.1%	34.4%
Overall Efficiency	86.30%	87.60%
Capital Cost	62,000	65,374
Installation Cost	16,400	26,000
Fuel	Natural Gas, propane, diesel; biogas	Natural Gas, propane, diesel; biogas
Comments	Turn-key co-generation systems with full service options available	Turn-key co-generation systems with full service options available
Website	www.cogenco.co.uk	www.cogenco.co.uk
Maintenance (3 year)	5,000	5,158
Maintenance (5 year)	6,700	6,738
Maintenance (10 year)	7,500	7,513
Engine Type	086 GV NX 86 (5.8 bar)	MAN E2876 E302 (9.4 ba
Generator Type	ECO38-1S	ECO38-1S
Barometric Pressure (kPa)	101.32	100
Length (mm)	3300	3300
Width (mm)	1250	1250
Height (mm)	2610	2610

Table 3: CHP Unit Specifications

Table 3 includes all the specifications necessary for the purpose of this project and served as an important organizational tool. It includes specific models and conveys a range of size options from each company as well as costs and electrical and thermal output. Many companies offer a maintenance plan for these units, and several companies offer various lengths of time for maintenance plans. A similar chart was used for each separate type of CHP equipment, including gas engines and fuel cells. The particular chart in Table 3 was specific to the comparison of gas piston engines.

With all this information on specific machines, we were able to analyze some of the costs that Merton could expect when purchasing, installing and operating such machines, and properly report them as needed in our technology guides.

3.3.2 Evaluate Waste-to-Energy Equipment

The procedure for the evaluation of fuel production equipment was similar to CHP, differing only in the type of data that needed to be collected on the equipment. The procedure followed the steps demonstrated by the flow chart in Figure 12. The two main types of fuel production equipment that were evaluated included anaerobic digestion plants and pyrolysis plants, both of which were specified as future possibilities by LBM.

We had originally planned to base our evaluations on an assessment of LBM's waste disposal needs including:

- Amount of waste produced
- Amount of waste removal needed
- Amount of energy produced
- Cost of energy produced

However, much of this research had already been conducted by LBM and Enviros Consulting Limited, a consulting firm working in collaboration with the boroughs of Kingston, Sutton, Croydon, and Merton. LBM outlined their current waste situation, the projected problems with waste disposal, and their proposed solutions to manage these issues in *London Borough of Merton Waste Management Strategy: 2006-2021*. Enviros Consulting Limited published a similar study for the boroughs of Kingston, Sutton, Croydon, and Merton in April of 2006 in a report entitled *Kingston/Sutton/Croydon/Merton: Materials Flow Modeling*. The study modeled the projected problems with waste disposal in each Borough based on the effects of a proposed mechanical biological treatment plant between the four boroughs. Both of these reports concluded that Merton would have to divert between 20,000 and 80,000 tonnes of biodegradable waste over the next 10-15 years in order to avoid the excessive £200 per tonne cost of landfill disposal. Thus, for the purposes of our guides, we did not focus on any specific range of available plants, but rather, gathered information on pyrolysis and anaerobic digestion plants of all sizes in order to show Merton their range of options should they decide to implement such a technology.

We were able to collect most of the specific data we needed for these technologies based on case studies and literature reviews, in particular, from feasibility studies which had been previously conducted. These studies included a range of specific detail on the types of systems available, waste capacities, and more importantly, the potential for energy generation based on the fuel produced. Some of the information which we gained from case studies for both pyrolysis and anaerobic digestion was organized in charts such as the one shown for pyrolysis in Table 4.

Pyrolysis Comparison		
Manufacturer	*Compact Power*	*Brightstar Environmental*
Waste Types	Municipal, Light Industrial, Commercial, Clinical, Hazardous	Residual mixed waste after separation of recyclables
Waste Volume	8,000 tonnes per year	30,000 tonnes per year
Energy Generation	0.5 MW	5.4 MW
Site Area	< 0.5 ha	1.2 ha
Building Footprint	26 m x 26 m	120 m x 100 m
Stack Height	12 m	70 m
Design Features	Simple industrial unit type building	Industrial with external piping network
Additional Information		
Lifetime of Facility	20-25 years	
Operational Hours	Potential 24 hours/7 days	
Building Height	15 m - 25 m	
Vehicle Movements	20 waste collection vehicles per day	
Employment	2-3 workers per shift	
Waste Storage	Single waste pit in main building with conveyor system.	
Chemical Storage	Small quantities of lime and urea or activiated carbon (for air pollution control)	
Ash Storage	Removed daily or weekly. Covered containers used.	

Table 4: Pyrolysis Case Study Comparison

Table 4 provides specifications of several units that meet the general criteria listed previously and was used to compare and contrast a number of options. In certain situations, additional information was provided that did not fit into the chart format and was included in the 'Additional Information Section' below the main chart. This chart served as an organization tool and a potential resource for our final deliverables.

Some of the specifications which we required were not provided by literature reviews or were too general for our needs. In order to gain a more specific range of plant specifications, especially regarding pricing, it became necessary to contact manufacturers.

Both pyrolysis and anaerobic digestion are fairly new commercially available technologies, and although there are a number of research plants which have been implemented throughout Europe and the UK, there were only a few manufacturers which actually manufacture and supply pyrolysis and anaerobic digestion plants in comparison to CHP equipment. In order to find these manufacturers, we conducted internet searches, literature review studies, and case studies. We were able to create a list of manufacturers for pyrolysis based on information from case studies, while we created a similar list of anaerobic digestion manufacturers based on a list provided by International Energy Agency (IEA) Bioenergy in a 2001 article *Biogas and More! System and Markets Overview of Anaerobic Digestion* (http://websrv5.sdu.dk/bio/pdf/biogas.pdf) along with various other sources. Initial research was conducted on each of these companies using manufacturer websites. Based on the information which we found, we were able to narrow our list of contacts to the following companies:

Pyrolysis Manufacturers

- Compact Power
- WasteGen UK
- Energos

Anaerobic Digestion Manufacturers

- Organic Waste Systems
- Valorga International SAS
- Kompogas AG
- Safe-Waste Systems Ltd.

Compact Power and Energos were the only two companies within the UK which were contacted by phone. As before, questions were asked on the spot based on the information we required. The remaining companies were located outside the UK, and as such, were contacted via e-mail. A general e-mail was created for pyrolysis manufacturers which can be found in Appendix B. The e-mail explained the purpose of our project and requested range of the following information:

- Plant type (Model)
- Cost (Capital, Operational, Installation, etc.)
- Waste Processing capability (Waste capacity)
- Typical waste streams/utilization
- Physical plant size
- Amount of land space required by the plant
- Net electrical output
- Usable heat output
- Any possible fuel output??
- Maintenance Plans

A similar e-mail, found in Appendix C, was sent to anaerobic digestion manufacturers, and requested similar information on anaerobic digestion plants:

- Plant type (Model)
- Cost (Capital, Operational, Installation, etc.)
- Waste Processing capability (Waste capacity)
- Feedstock
- Physical plant size
- Amount of land space required by the plant
- Electricity production
- Biogas production (Any other fuel output??)
- Maintenance Plans

Each e-mail was slightly altered based on the company being contacted.

All manufacturer data for pyrolysis and anaerobic digestion which we were able to collect was compiled and organized into a spreadsheet such as that shown in Table 5.

Pyrolysis Comparison		
Company	*Compact Power*	*Compact Power*
Model	Multi-Tube 2 (MT-2)	Multi-Tube 4 (MT-4)
Waste Processing Capability (metric tonnes p.a.)	5,500	9,300
Net Electrical Output (MWe)		0.8
Usable Heat Output (MWth)		2.4
Typical Waste Streams/Utilization	MSW, Clinical, Pharmaceutical, Sewage, Industrial	MSW, Clinical, Pharmaceutical, Sewage, Industrial
Price Range	3.5 mil.	8 mil.
Operation (days/wk)	5	5
Operation (wks/yr)	7500	7500
Website	www.compactpower.co.uk	www.compactpower.co.uk
Annual Maintenance	1 two week shut down 3 five day shutdowns	2 two week shut down 3 five day shutdowns
Plant Size (L x W x H) m		
Land Area Required (m)		
Stack Height (m)		
Porfit/Expense Break ($/tonne)	120	
Comments		

Table 5: Pyrolysis Plant Specifications

Table 5 was organized similar to the spreadsheets created for the CHP units and includes a range of available units and an overview of all the necessary specifications for a waste-to-energy plant relevant to Merton's needs and the purposes of our project including model type, waste capacity, acceptable waste, pricing, etc. A similar spreadsheet was created for anaerobic digestion.

The collected information on commercially available units provided solid evidence and data so that LBM could understand the potential outcome for alternative energy production. More specifically, this information was directly relevant for inclusion in a technology guide as it provided essential basic information on the range of units available, their specifications, and the economic and environmental impact of each.

3.4 Create Communication and Educational Outreach Tools for the Borough of Merton

As a final outcome for the Borough of Merton, our team created three different versions of an energy technology guide. These guides were primarily created as educational outreach tools for the community and other interested audiences and communication tools for policymakers and members of the Merton council regarding available energy technologies and associated units. Each guide encompassed our previous technology and equipment research. Not every technology was included in each guide, but the following technologies were covered throughout all three guides:

- District heat and power
- Combined heat and power
- Hydrogen fuel cells
- Pyrolysis
- Anaerobic digestion

Although we conducted large amounts of research and obtained numerous figures and data ranges for various units, we were able to condense our research in different forms so as to present all of the information in a clear and easy to understand manner. We loosely based the design and content of our guides on an explicit set of questions outlined by our liaison, Mr. Adrian Hewitt, prior to our arrival. Not all of the questions were answered within each version, but the list provided a general rubric for each of our final outcomes. The following list of questions was presented to us:

- What different types of machines are there?
- What companies manufacture such products?
- Where is the technology in place currently?
- What is the total capital expense? How much does a unit cost?
- What is the annual expense of running this technology?
- What sizes do they come in?
- What is the physical land space necessary for installation?
- How does the technology operate/work?
- What is the energy generation?
- What are the main advantages of the technology?
- What are possible disadvantages or potential products of the technology?

We provided different levels of explanation regarding each of these questions and complemented our work with basic diagrams. The following sections will briefly explain each of our guides including in what form it was written, what was included, and the overall intentions of it.

3.4.1 Version 1: Online Interactive Technology Guide

Our original goal for this project was to create a Layman's Guide which would communicate to and help educate policy makers on the technologies which Merton planned to implement in the future. The guide would be written in a way which we believed would be easy to understand, and created in an easily accessible format for the use of neighboring boroughs, and more importantly, other future Energy Action Areas.

With these ideas in mind, we decided to create our initial version of the technology guide using Microsoft PowerPoint. Not only did PowerPoint allow us the freedom of creativity with animation, colors, and interactive tools, but the limited amount of space per slide controlled the level of detail and depth which we could include on each slide and prevented overwriting or technical descriptions. The PowerPoint was intended to be a non-technical guide specifically designed as a presentation and communication tool, and a potential online tool which people could use at their own pace. It was created with key policymakers and decision makers of LBM in mind, but was formulated in a replicable manner that could be used by Merton Council, students, or other interested audiences or boroughs.

The guide included information on district heat and power, combined heat and power, hydrogen fuel cells, pyrolysis, and anaerobic digestion. Each technology was outlined in a similar manner and explained such that all the previously outlined questions were answered. Explanations were brief and bulleted so they could be easily followed, and were written in a non-technical manner to ensure that policymakers and other users could comprehend the information given. A number of pictures and colors were included as explanatory supplements.

To incorporate more active participation from the reader, we included information at varying levels of detail and designed the guide such that the reader could decide the depth to which the information is explained. A straight path touching upon only the fundamental processes and specifications was included for those readers who desired a quick and basic overview. However, for those readers who desired more detail, additional slides providing more in depth explanations were added as hyperlinks. Many of the explanations included animations and were offered in a medium beyond plain text.

3.4.2 Version 2: Technology Brochure

It became apparent that a hard copy was going to be needed for further distribution as the Interactive guide was not in a printable format. As a supplement to the PowerPoint, and a more replicable model for municipalities and future Energy Action Areas, we created a several page handout on alternative energy technologies. The handout was designed to be a more manageable form that could easily be distributed or potentially viewed online.

In order to convey the information in the most appealing manner, we decided that a one page three column synopsis made in Microsoft Publisher would be the best option. The handout covered the four main technologies on which we focused most of our research: combined heat and power, hydrogen fuel cells, pyrolysis, and anaerobic digestion. The overall purpose of the handout was to summarize what we believed to be the key points of each of these technologies in a portable paper format. Each technology was summarized on a single page based on the template shown in Figure 14.

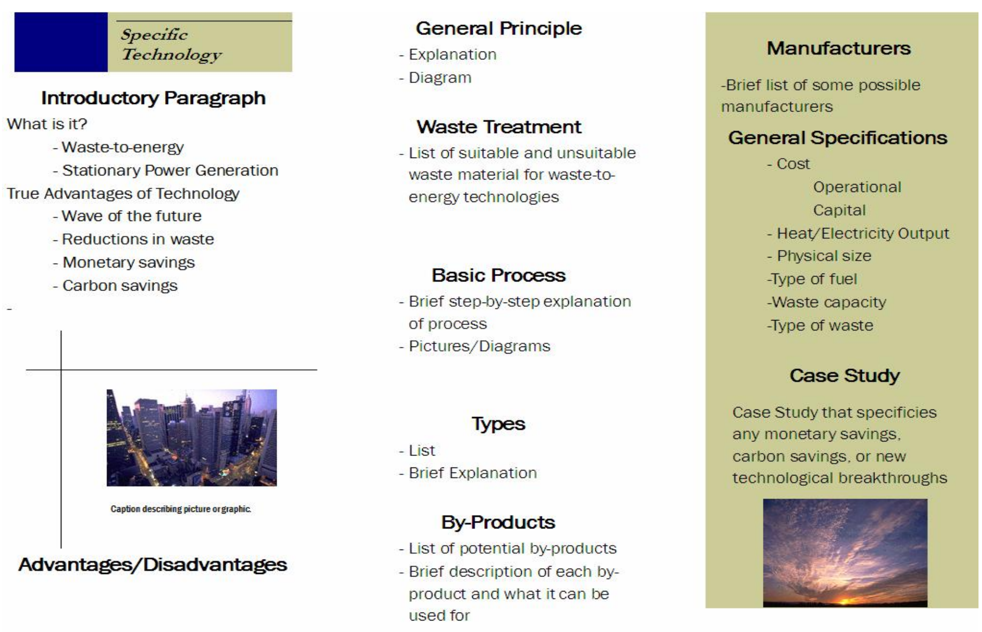

Figure 14: Template for Layman's Guide Brochure

The general format of Figure 14 was altered based on the type of technology covered, but followed the same basic three column outline. A number of pictures and colors were added for visual stimulation and explanations.

3.4.3 Version 3: Technical Report

Since we conducted in depth research and had already written much of the details, we decided that it would be desirable to include a technical report on each technology to serve as a reference for those readers who desired more detail than what was found in the other two guides. We included information on all five technologies proposed by the Borough of Merton including district heat and power, combined heat and power, hydrogen fuel cells, pyrolysis, and anaerobic digestion. Each technology was introduced with a brief introductory paragraph followed by a detailed description of what it is, how it works, the different types, advantages and disadvantages, and some relative operating examples. No information was included regarding equipment specifications or available units.

The guide was not specifically designed for Merton council members, but rather as a reference tool for students, planners, or other interested audiences. It was written in Microsoft Word in the form of a technical research report, and included a compilation of all our background preparation research. The primary purpose of this version was to provide an additional educational tool for the Borough of Merton which would encompass a more technical audience in comparison to our previous deliverables.

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3.5 Conclusion

Through extensive research on CHP, pyrolysis, hydrogen fuel cells and anaerobic digestion, and a detailed comparison of commercially available alternative energy technologies, our team has gained enough knowledge on these technologies to effectively communicate our research to audiences of both a technical and non-technical background. The communication tools which we have created establish a necessary means of communication between policymakers and engineers. In combination with the work of engineering and consultancy firms, our guides bridge the gap between the two levels of CHP/DHP decision makers by linking together the research and planning specifications necessary to begin implementation of a CHP/DHP system. The guide and the various forms of it will be utilized as an informational tool to educate people to a level of general comprehension of available renewable energy technology and the gains and losses associated with these technologies. The final outcome will provide the people of Merton with knowledge with which to make wise decisions about reducing energy consumption and carbon emissions in the London Borough of Merton.

Chapter 4: Results

Over the course of this project, we were able to build a substantial list of resources and necessary information for the completion of our work. This chapter will detail much of the information and results we gathered from these resources including the energy demands and power loads for the Mitcham area upon which we based our research; a compilation of the data we received from manufacturers, case studies and literature reviews regarding available equipment in the UK; and a general overview of each of the three technology guides, including the general layout and various thoughts. Not all of our research could be included within this chapter due to the extensive amount of detail. However, our results reflect the amount of information and depth to which we collected our data, as well as how we condensed the research and portrayed it in such a way that all the necessary information was understandable and easily accessible to any type of audience.

4.1 Energy Demands and Power Loads for the Mitcham Area

Before we could begin contacting CHP manufacturers, we needed to gather data on energy demands and power loads in the Mitcham area in order to focus our research on properly sized equipment and provide manufacturers with relative data. We were able to acquire energy and heat demands from two main sources:

- Parsons Brinkerhoff Interim Report
- Laser Audit

The Parsons Brinkerhoff interim report was provided to us by Mr. Hewitt. The laser audit, however, was obtained from the second team of WPI students working for the Borough of Merton. They found the audit from a source in Merton council and helped provide us with necessary information.

Table 6 contains all the energy demands we obtained from these sources as well as the electricity and thermal loads we calculated based on these demands. The data is organized by heat demand, electrical demand, thermal load, and electrical load. The last column of the table indicates whether the site is a future development, signifying that the building has not yet been built or has not begun operation.

Energy Demands and Power Loads for Mitcham					
Building Name & Description	**Annual Average Heat Demand (kWh)**	**Average Annual Electricity Demand (kWh)**	**Average Annual Thermal Load (kW)**	**Average Annual Electrical Load (kW)**	**Future Development (Y/N)**
Canons Leisure Center	1,552,271	778,849	177	89	N
Nursing Home and Day Centre	544,128	N/A	62	N/A	N
Supermarket - Town Centre	1,724,100	4,353,041	197	497	N
Residential (Supermarket) - Town Centre	2,616,000	1,650,000	299	188	Y
St Marks Primary School	246,397	54,271	28	6	N
Elm Nursery Estate	1,974,426	792,000	225	90	N
Glebe Estate	2,229,050	762,300	255	87	N
Sadlers Close Estate - Town Centre	2,814,380	947,100	321	108	N
Glebelands Retirement Home	1,019,616	264,000	116	30	N
Gas Works - Mixed Use Site	N/A	N/A	N/A	N/A	Y
Peter and Paul's RC Primary School	283, 123	112, 439	32	13	N
The Vestry - Town Hall	71,243	80,432	29	9	N
Fire Station	180,096	N/A	21	N/A	N
Cricket Green School	211,649	56,474	30	6	N
Worsfold House	227,336	130,609	26	15	N
Melrose School	271,560	N/A	30	N/A	N
Baron Estate	701,088	336,600	80	38	N
Wilson Cottage Hospital	6,284,800	N/A	717	N/A	Y
Cranmer Middle School	454,425	N/A	77	N/A	N
Jan Malinowski Centre	629,833	94,000	72	11	N
Mitcham Garden Village Retirement Home	481,496	165,000	55	19	N
Eastfields Estate	3,960,188	702,900	452	80	N
Mitcham Vale School (inc Youth Centre)	1,296,669	1,040,882	148	119	N
Laburnum Estate	1,021,984	277,200	117	32	N
EP Brenley	654,000	396,000	75	45	Y
EP Rowan	1,744,000	1,155,000	199	132	Y
Gardens Primary School	814,028	N/A	93	N/A	N
St. Thomas of Canterbury	499,602	N/A	581	N/A	N
The Sherwood Primary School	462,468	N/A	53	N/A	N
Benedict Primary School	417,400	N/A	48	N/A	N
Lonesome Primary School	414,286	N/A	47	N/A	N
Bond Primary School	382,187	N/A	44	N/A	N
William Morris Primary School	342,536	N/A	39	N/A	N
Gorringe Park Primary School	338,601	N/A	39	N/A	N
Chapel Orchard	323,525	N/A	37	N/A	N
Pollards Hill Day Centre	219,092	N/A	25	N/A	N
Pollards Hill Youth Centre	188,029	N/A	21	N/A	N
Phillips Bridge	123,848	N/A	14	N/A	N

Table 6: Average Annual Energy Demands and Power Loads for Mitcham

Some data was unavailable or not provided by the sources and is indicated in Table 6 by an "N/A". Bold figures in the table signify actual data obtained by Parsons Brinkerhoff. Any figures which are not darkened signify approximated data based on benchmark figures from the CIBSE guide. All of the data between Garden's Primary School and the conclusion of the table was obtained from the Laser Audit. Because Laser only provides thermal data, no electrical data was recorded for these buildings.

After the table was complete, the team grouped clusters of buildings together which could potentially be supplied by a CHP unit. Based on the data in the table, we deduced that mid-size CHP units would provide the optimal amount of power for these sectors. We were able to eliminate large-scale CHP manufacturers and mini/micro manufacturers from our list of manufacturers.

In addition, we were able to include much of this data in our technology guides by using specific buildings relative to the Borough of Merton to demonstrate the power capabilities of a variety of combined heat and power units. It was important to provide examples which Merton council was familiar with as well as general examples to which any Borough or audience could relate.

4.2 Evaluation and Comparison of Available Equipment

Technological maturity plays an important role in the amount of information available. Technology, such as CHP fueled by natural gas, has been around for a number of years, while technologies such as hydrogen fuel cells, pyrolysis, and anaerobic digestion have only just begun to rise in commercial development. As our result, it became evident during our evaluation that the availability of information and the number of manufacturers was far greater for CHP than any of the other technologies, a limitation which is reflected in the following results.

4.2.1 CHP Production Equipment

Of the six manufacturers we contacted, four companies that distribute and install CHP systems in the United Kingdom responded with sufficient results on CHP unit specifications. Data was obtained for 39 different CHP units from the following companies:

- Aircogen
- Cogenco
- Clarke-Energy
- Ener-G

Information on 17 different models were collected from Aircogen, nine models from Cogenco, seven models from Clarke-Energy, and six units from Ener-G. A sample of the information provided by Aircogen, Cogenco, and Ener-G can be found in Appendix D. The data gathered was put into a chart, a sample of which is displayed in Table 7.

We had contacted two additional companies: Xergi and E on UK. However, Xergi was unable to provide us with necessary information and E on UK recently discontinued CHP sales and installation.

Reciprocating Engine CHP Comparison		
Company	Cogenco	Cogenco
Model	CGC-0082-L-NGUK-50	CGC-0130-L-NGUK-51
Type	Gas Engine	Gas Engine
Engine Manufacturer		M.A.N.
Electrical Power (KW)	82	130
Thermal Power (KW)	132	201
Electrical Efficiency	33.1%	34.4%
Overall Efficiency	86.30%	87.60%
Capital Cost	62,000	65,374
Installation Cost	16,400	26,000
Fuel	Natural Gas, propane, diesel; biogas	Natural Gas, propane, diesel; biogas
Comments	Turn-key co-generation systems with full service options available	Turn-key co-generation systems with full service options available
Website	www.cogenco.co.uk	www.cogenco.co.uk
Maintenance (3 year)	5,000	5,158
Maintenance (5 year)	6,700	6,738
Maintenance (10 year)	7,500	7,513
Engine Type	086 GV NX 86 (5.8 bar)	MAN E2876 E302 (9.4 ba
Generator Type	ECO38-1S	ECO38-1S
Barometric Pressure (kPa)	101.32	100
Length (mm)	3300	3300
Width (mm)	1250	1250
Height (mm)	2610	2610

Table 7: CHP Unit Comparison

An entire version Table 7, including all thirty-nine units, can be found in Appendix E.

For better searching capabilities, a data base was made in Microsoft Access, a screenshot of which can be seen in Figure 15. This database was created in conjunction with the second WPI team working with the Borough of Merton. The database allows the user to easily search through the entire collection of units by company, type or fuel type. It also allows the user to input an annual heating or electricity demand and provides a range of units that could provide adequate power for such a demand. The spreadsheet includes a detailed financial analysis of each machine which is explained in greater detail in the other WPI team's IQP report: *Carbon Reduction Tools for Municipal Buildings.*

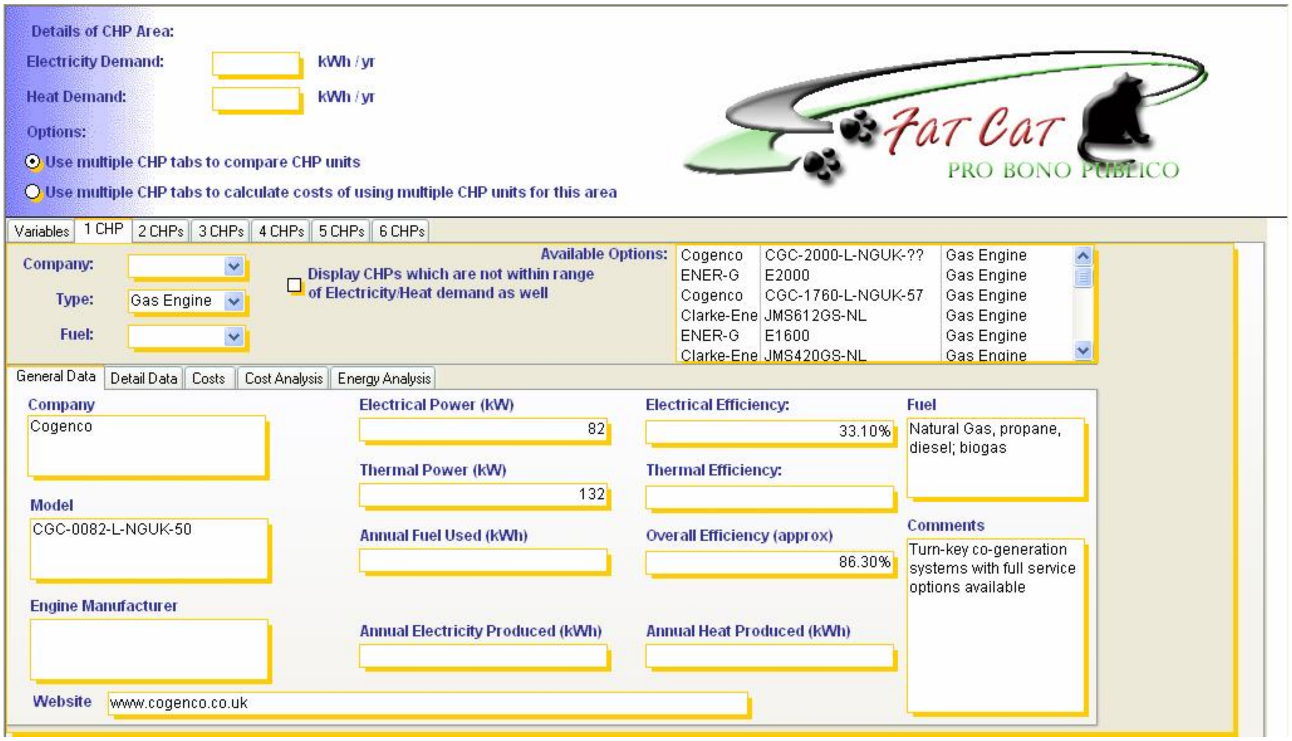

Figure 15: Microsoft Access Screenshot of CHP Database

4.2.2 Pyrolysis Plants

Pyrolysis is an emerging technology that, in the future, has real potential to reduce the amount of waste municipalities transport to landfills. Since it is fairly new, there is little diversity in the number of suppliers. Case studies have encompassed much of our research due to the low number of manufacturers available. An important result of the pyrolysis section was the comparison completed in Table 8. While pyrolysis is of interest for Merton, it still may be at least 3-5 years before actual implementation. We have provided basic planning information which may be more useful than pricing of equipment available today.

Pyrolysis Comparison		
Manufacturer	*Compact Power*	*Brightstar Environmental*
Waste Types	Municipal, Light Industrial, Commercial, Clinical, Hazardous	Residual mixed waste after separation of recyclables
Waste Volume	8,000 tonnes per year	30,000 tonnes per year
Energy Generation	0.5 MW	5.4 MW
Site Area	< 0.5 ha	1.2 ha
Building Footprint	26 m x 26 m	120 m x 100 m
Stack Height	12 m	70 m
Design Features	Simple industrial unit type building	Industrial with external piping network
Additional Information		
Lifetime of Facility	20-25 years	
Operational Hours	Potential 24 hours/7 days	
Building Height	15 m - 25 m	
Vehicle Movements	20 waste collection vehicles per day	
Employment	2-3 workers per shift	
Waste Storage	Single waste pit in main building with conveyor system.	
Chemical Storage	Small quantities of lime and urea or activiated carbon (for air pollution control)	
Ash Storage	Removed daily or weekly. Covered containers used.	

Table 8: Pyrolysis Case Studies Comparison (Enviros Consulting, 2004)

Similar to CHP, manufacturers of pyrolysis were also contacted. Of the three companies we called and e-mailed, only two companies responded or were willing to provide information. We received a number of details from Compact Power on the three plants which their company supplies. Information on these plants can be found organized in Table 9. Ener-G was willing to help, but only had a research scale pyrolysis plant which was unavailable for commercial manufacturer or supply. However, they were able to provide us with general details on waste capacity and cost which were taken into account during the creation of our technology guide. The only company which we were unable to get a hold of was WasteGen UK. Fortunately, their website did provide adequate details for the information we needed.

Pyrolysis Comparison			
Company	*Compact Power*	*Compact Power*	*Compact Power*
Model	Multi-Tube 2 (MT-2)	Multi-Tube 4 (MT-4)	Multi-Tube 8 (MT-8)
Waste Processing Capability (metric tonnes p.a.)	5,500	9,300	30,000
Net Electrical Output (MWe)	0.28	0.8	2.2
Usable Heat Output (MWth)	2.5	2.4	8 *Note: In the form of hot water (70C)
Typical Waste Streams/Utilization	MSW, Clinical, Pharmaceutical, Sewage, Industrial	MSW, Clinical, Pharmaceutical, Sewage, Industrial	MSW, Clinical, Pharmaceutical, Sewage, Industrial
Price Range	3.5 mil.	8 mil.	10 mil.
Operation (days/wk)	5	5	5
Operation (wks/yr)	7500	7500	7500
Website	www.compactpower.co.uk	www.compactpower.co.uk	www.compactpower.co.uk
Annual Maintenance	1 two week shut down 3 five day shutdowns	2 two week shut down 3 five day shutdowns	3 two week shut down 3 five day shutdowns
Plant Size (L x W x H) m			30 x 25 x 12
Land Area Required (m)			30 x 50
Stack Height (m)			18
Porfit/Expense Break ($/tonne)	120		60
Comments			MSW should pass a sieve of 100mm x 100mm. Avoid larg car parts, vacuum cleaners and so forth.

Table 9: Pyrolysis Plant Specifications from Compact Power

4.2.3 Anaerobic Digestion Plants

Like pyrolysis, anaerobic digestion is a developing waste-to-energy technology with the potential to reduce the projected growths in waste in urban areas. It has been around for years on farms and in cities for the treatment of animal waste and wastewater; however, anaerobic digestion plants for the treatment of municipal solid waste have only just begun to rise in commercial manufacture and availability. As a result, most of our data was based on case studies and feasibility studies from which we were able to gather general equipment specifications. One of the primary results of our research for anaerobic digestion was the comparison of anaerobic digestion units in Table 10. Although we were not able to gather a large amount of information, we were able to provide Merton with key information ranges on plant size and cost to give them an idea of what to expect in the decision to implement an anaerobic digestion plant.

Anaerobic Digestion Case Study				
Company	Greenfinch Ltd. Demonstration Project (funded by UK Dep. Trade & Ind.)	Biffa Waste Services	Valorga International	Organic Waste Systems
Location	Tenbury Wells, Worcestershire	Wanlip Sewage Works, Leicester	Tilburg, Netherlands	Brecht, Belgium
Setting	Rural	Urban		
Waste Types	Organic Kitchen Waste	Organic household waste	Vegetable, fruit and garden waste and non-reusable paper and card	Source seperated organic
Waste Volume	315 tonnes in 18 months	Organic waste fraction from 117,000 homes	46,000 - 52,000 tonnes per year	10,000-15,000 tonnes per year
Fuel Generation	140 cu. m. / week biogas	Methane	83-106 m^3/tonne of biogas (55% methane)	107m^3/tonne of biogas (55% methane)
Energy Generation	Converted to heat	approx. 1.5 MW electricity	18 GWh per year	290 kW
Site Area	behind a garden center		1.6 hectacres	
Building Footprint		approx. 0.5 ha.		
Design Features	In a full scale model, components could be easily housed within lowrise building structures	• All waste handling to be carried out in enclosed building with air filters to control odor and dust • Integration with existing sewage plant • Low traffic levels of approx. 8 loads per day, confined to main road network	• 2 digesters, each with a capacity of 3,300 m^2 per year • Dry, single step, mesophilic plant	• 1 digester, 21 metres high, with a capacity of 808 m^3 • Dry, single step, thermophilic plant
Comments	Project demonstration succesful, conclusions of project • Full scale operation should include o 10,000 households minimum o 2,200 tons/annum minimum o Land of approx. 1/10 ha. o Process can be profitable for a fee of $50-60/ton		Produces 18,000 tonnes of compost per year	

Table 10: Anaerobic Digestion Case Studies (Enviros Consulting, 2004; Wannholt, 1999)

Of the four companies we contacted that commercially manufacturer and supply anaerobic digestion plants around Europe, we received responses from two companies: Safe Waste Systems and Organic Waste Systems. Safe Waste Systems did not manufacturer any plants beyond research scale and was unable to provide us with any information. Organic Waste Systems, on the other hand, is one of the few commercial manufacturers of anaerobic digestion plants in the UK and provided us with a number of detailed charts and reports on anaerobic digestion plant specifications. Most of the key information was organized into Table 11. The remainder of the reports and charts can be found in Appendix F.

Anaerobic Digestion					
Company	Organic Waste Systems	Organic Waste Systems	Organic Waste Systems	Organic Waste Systems	Organic Waste Systems
Waste Processing Capability^ (metric tonnes p.a.)	5,000	10,000	25,000	50,000	100,000
Net Electrical Output	130 kWe	260 kWe	640 kWe	1.3 MWe	2.6 MWe
Surplus Electrical Output	**80 kWe**	**160 kWe**	**410 kWe**	**850 kWe**	**1.7 MWe**
Net Usable Heat Output	170 kWth	340 kWth	850 kWth	1.7 MWe	3.4 MWe
Surplus Heat Output	**154 kWth**	**310 kWth**	**770 kWth**	**1.5 MWe**	**3.1 MWe**
Price Range	£6.3 Million	£8.3 Million	£10.4 Million	£13.9 Million	£20.8 Million
Operational Cost*	£140,000	£210,000	£430,000	£690,000	£1,040,000
Website	http://www.ows.be/	http://www.ows.be/	http://www.ows.be/	http://www.ows.be/	http://www.ows.be/
Plant Blueprint (m^2)	3000	4000	7000	10000	15000
*does not incude annunity, personnel, cost of consumables,maintenance and insurance costs					
^ Type of waste utilized: biowaste, organic fraction of grey waste, industrial organics, paper waste, market waste, manure, sewage sludge					

Table 11: AD Plant Specifications from Organic Waste Systems

4.3 Communication Tools for the Borough of Merton

We compiled all of our research into three different versions of an energy technology guide. Each version was devised specifically based on the audience, and, together, were designed to reach a number of people, regardless of their technological background.

For the purposes of our audience and as a way to keep the team on track, we followed a general rubric for each guide so that every technology would be outlined and explained in a similar manner. During our research, we were faced with certain limitations when we found that the amount of available information varied on each technology, an obstacle which was reflected in our final outcomes. In particular, there are noted differences in each guide regarding the equipment specifications for waste-to-energy technologies in comparison to CHP and hydrogen fuel cells.

A general overview and the final layout of each version of the guide can be found in the following sections.

4.3.1 Version 1: Progressive Technologies for a Greener Future – An Interactive Guide to Emerging Energy Technologies

Progressive Technologies for a Greener Future is an interactive PowerPoint guide based on our original idea to create a Layman's Guide. The PowerPoint covers each of the technologies outlined in the methodology and answers all of the proposed questions.

The guide is written in general terms which we intended to be easy to understand. It was created with Merton council policymakers in mind, but was designed for any audience with a non-technical background. Each slide contains the same background image and is characterized by brief writing, basic pictures, cartoons, and animation for visual stimulation and to help visually explain some of the more complex topics. Most of the pictures were obtained from either clip art or various online sources which we cited directly on each slide. Figure 16 contains an illustration of our title slide.

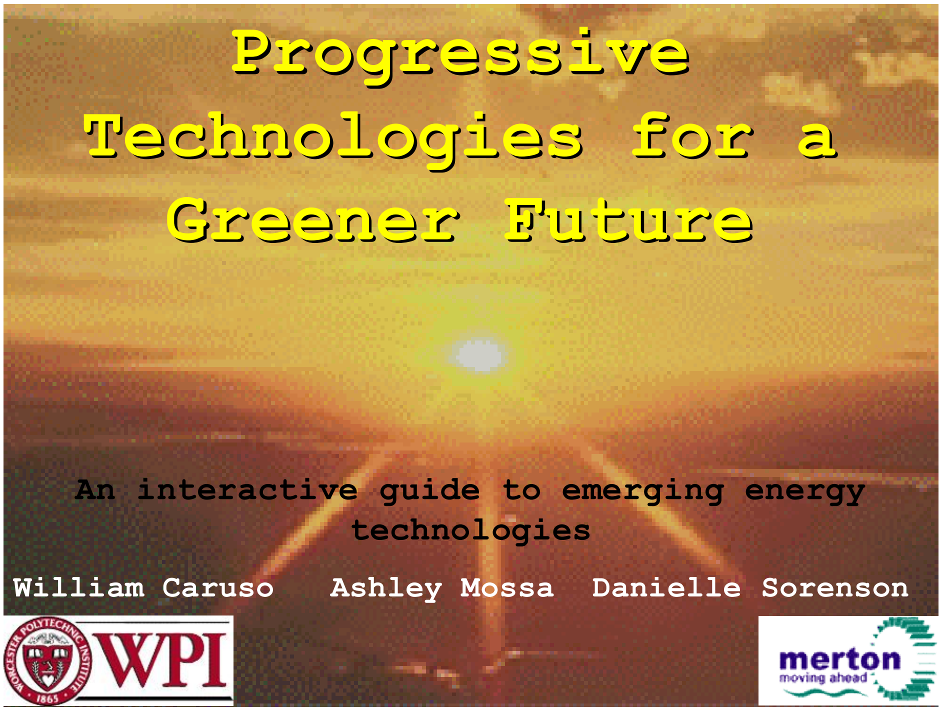

Figure 16: *Progressive Technologies for a Greener Future* - Title Slide

The guide is organized into chapters by technology, each of which is color coded and similarly outlined. Every chapter is comprised of a group of main slides which briefly answers each of the questions on which we focused our research. The slides include a brief level of detail and incorporate animation and pictures for explanation purposes. From these slides, we added hyperlinks to additional slides which include more detailed information. Each hyperlinked slide contains the same four buttons and can be navigated in the forward or backward direction. At any point in the detailed slides, a user can return to the original hyperlinked slide or the table of contents and continue through the main guide. This interactive set-up was designed to incorporate reader interaction by allowing users the opportunity to choose how much information and depth they desire on a particular technology. Detailed instructions on how to use this feature are included in an introductory instructions slide (Figure 17).

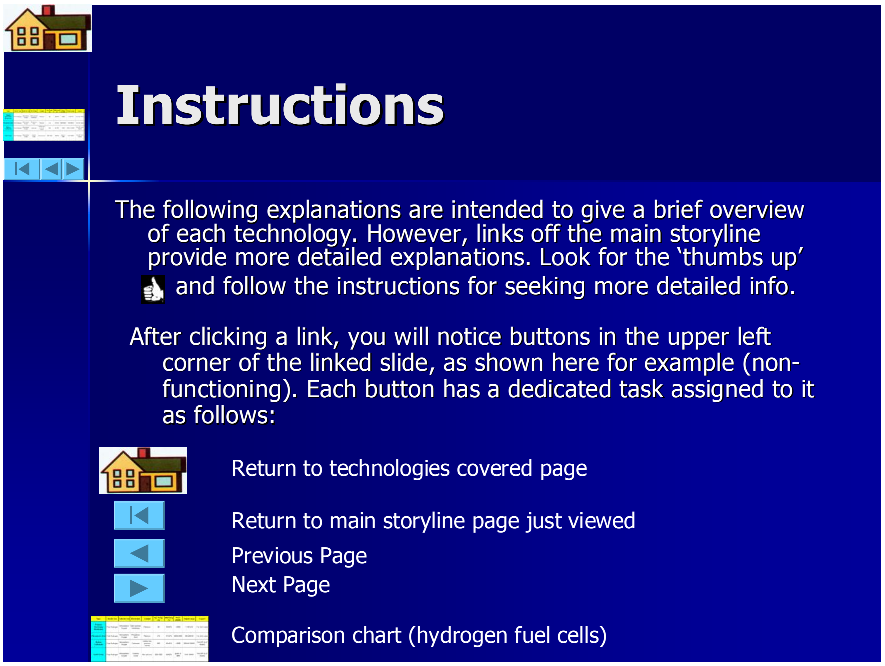

Figure 17: *Progressive Technologies for a Greener Future* - Introductory Instructions Slide

The guide begins with a brief explanation of district heat and power as shown in Figure 18. This section is composed of only a few slides, and is primarily included as a preface for CHP and the rest of the guide, which focuses on technologies which could be implemented in combination with a CHP/DHP network.

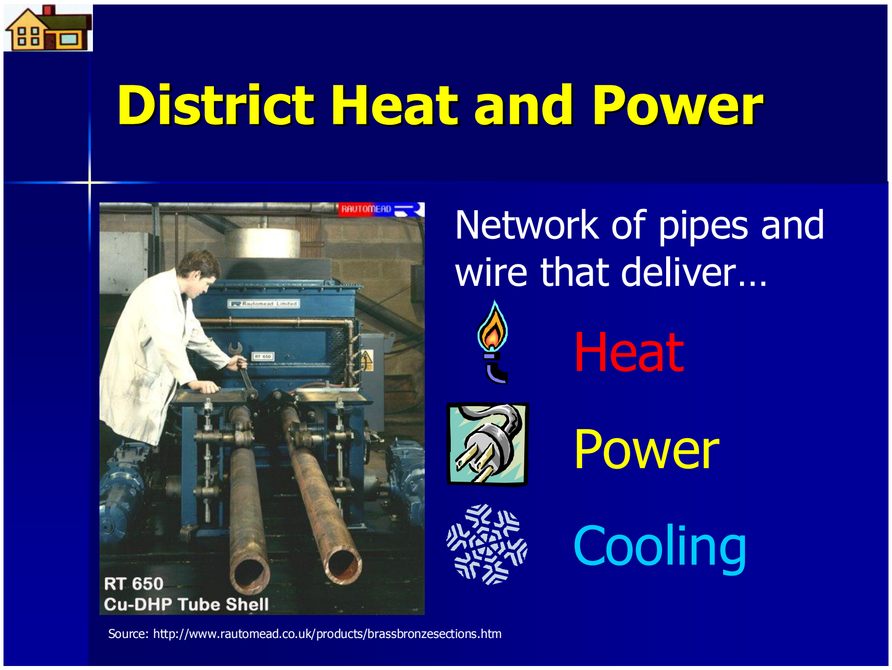

Figure 18: Explanation of District Heat and Power

Detailed explanations follow on the two power generation technologies: combined heat and power and hydrogen fuel cells. The principle of combined heat and power and the numerous types of combined heat and power units are explained using images and brief descriptions, such as that shown in Figure 19 for a steam turbine.

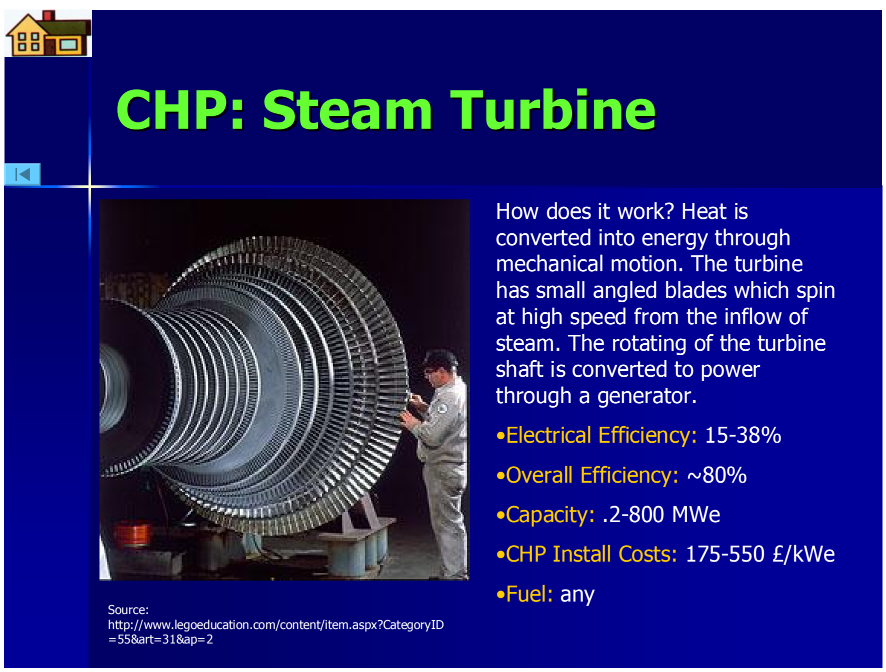

Figure 19: Example of a Steam Turbine and how it Works

One of the most important aspects of power generation systems such as combined heat and power units is the amount of power which can potentially be generated from a single unit. A highlight of the CHP section is the visual representation used to explain this idea, shown in Figure 20. This picture demonstrates power generated by a CHP unit relative to supplying building energy demands. It provides an easy to understand explanation of power and what it means and how it applies to communities, a topic which is touched upon in every other section.

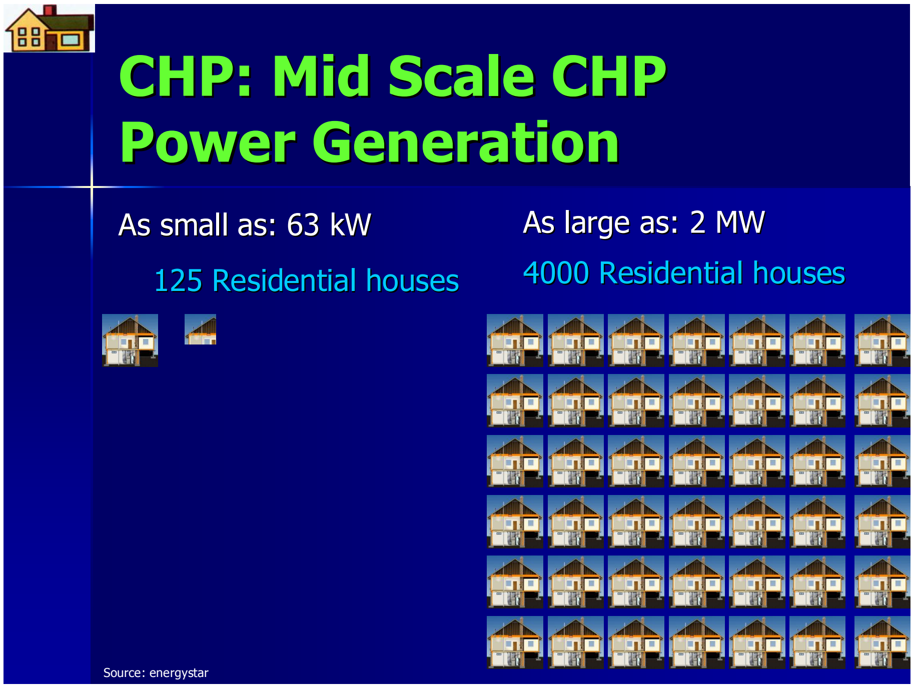

Figure 20: CHP Power Generation Relative to the Supply of Building Energy Demands

Because fuel cells are an alternative form of power generation technology, they logically follow in the chapter after CHP. The principle of fuel cells is explained within the first few slides, but the major obstacle was describing hydrogen fuel cells such that all audiences could understand. An interactive diagram of a basic fuel cell is used in an attempt to easily explain the setup and function of a fuel cell. Figure 21 was designed such that a person could click on any component of the fuel cell and be directed toward an alternate slide with an explanation of that particular component. This section includes a number of similar interactive features, and is highlighted by the most hyperlinks and interactive aspects of all the chapters.

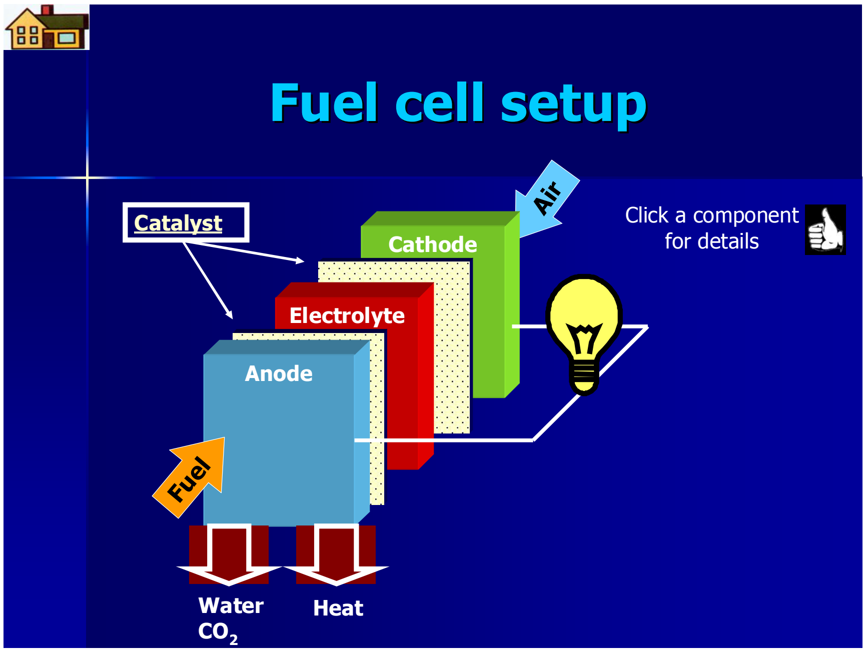

Figure 21: Interactive Display of How a Fuel Cell Works

A transition follows hydrogen fuel cells from power production technologies to waste-to-energy technologies including pyrolysis and anaerobic digestion. Both of these technologies are similar in principle and are each outlined in a similar manner including explanations on the following topics:

- The principle of the technology
- Acceptable and unacceptable types of waste
- How it works
- Potential by-products
- General plant specifications
- Various operating examples
- Advantages and disadvantages, including economic and environmental

Because these technologies are still both fairly new on a commercial scale and have not been implemented throughout the UK, most of the explanations for pyrolysis and anaerobic digestion are highlighted by a number of diagrams and basic pictures. This was purposely done so that audiences could understand how each technology works, even if just through pictures. A few example slides taken from the pyrolysis and anaerobic digestion section can be seen in Figures 22 and 23.

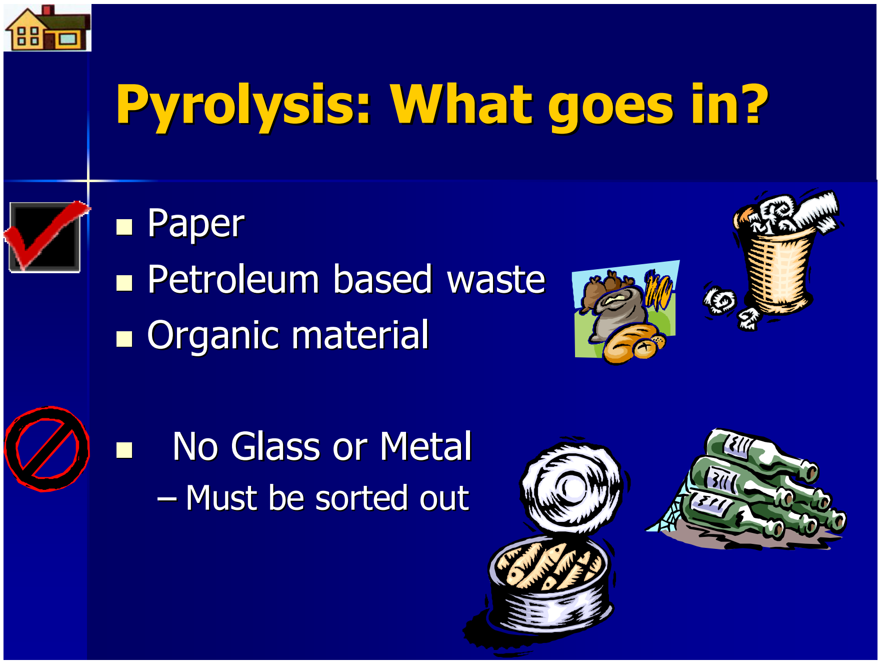

Figure 22: Ideal Waste Inputs for a Pyrolysis Plant

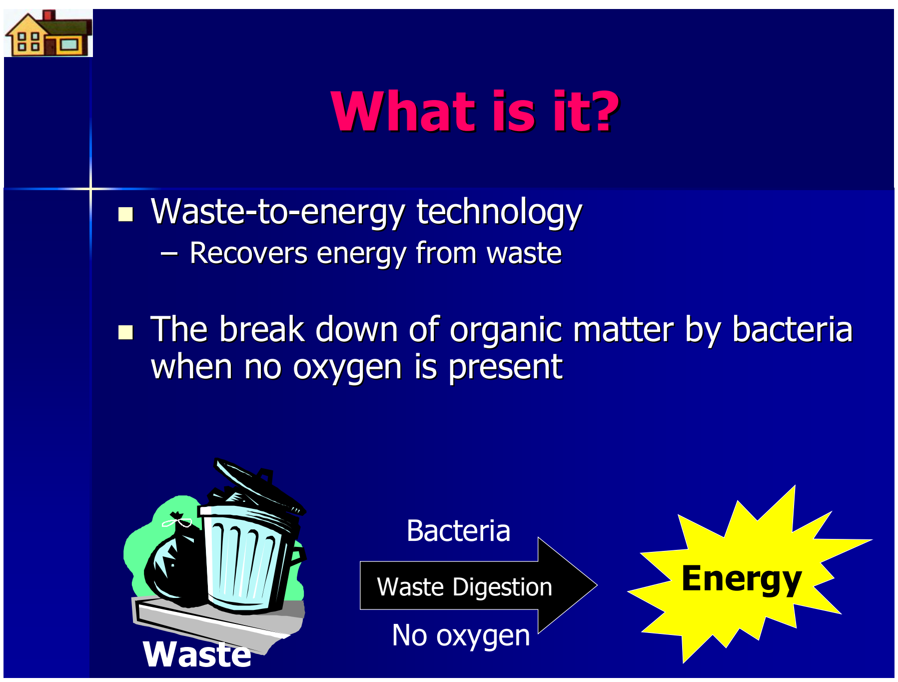

Figure 23: Brief Description of the Principle of Anaerobic Digestion

This guide will be fully accessible to the public on the London Borough of Merton Council website.

4.3.2 Version 2: Progressive Energy Technologies – An Informational Guide to Available Efficient Energy Systems

Progressive Energy Technologies is a brief reference guide to alternative energy systems that was developed based along the same principle as *Progressive Technologies for a Greener Future*, but was designed as a complementary handout to the interactive PowerPoint. It includes brief information on the four primary technologies including combined heat and power, hydrogen fuel cells, pyrolysis, and anaerobic digestion, and touches upon what we feel are the key fundamentals of each technology. It is written in a non-technical manner similar to the PowerPoint and was designed in Microsoft Publisher as a several page handout for policymakers in Merton council and as a potential educational tool for those with a non-technical background. The handout is intended to be a more manageable, accessible form of our original guide that could be easily carried, handed out, or viewed online.

The handout is composed of 10 pages including a title page, a detailed introductory page outlining the purpose of this report (Figure 24), a one page explanation for each of the four technologies, and 4 pages of references with an individual list of resources for each technology.

Figure 24: Introduction to *Alternative Energy Technologies*

All four technology pages are characterized by a unique background and color scheme, and are formatted with the same general layout. The technologies are ordered as before with combined heat and power and hydrogen fuel cells at the beginning, and pyrolysis and anaerobic digestion at the end.

Combined heat and power and hydrogen fuel cells are both similarly formatted. The discussion of each technology includes the following information:

- A brief introduction at the beginning describing the technology and its importance
- A small list of the most important advantages and disadvantages
- An outline of the basic principle
- A brief explanation of how it works
- A list of the different types
- A list of manufacturers
- A short description of a relevant case study

A number of pictures from the PowerPoint are used to enhance the explanations and create a visually stimulating work attractive to all types of audiences. Figure 25 contains the page created for hydrogen fuel cells.

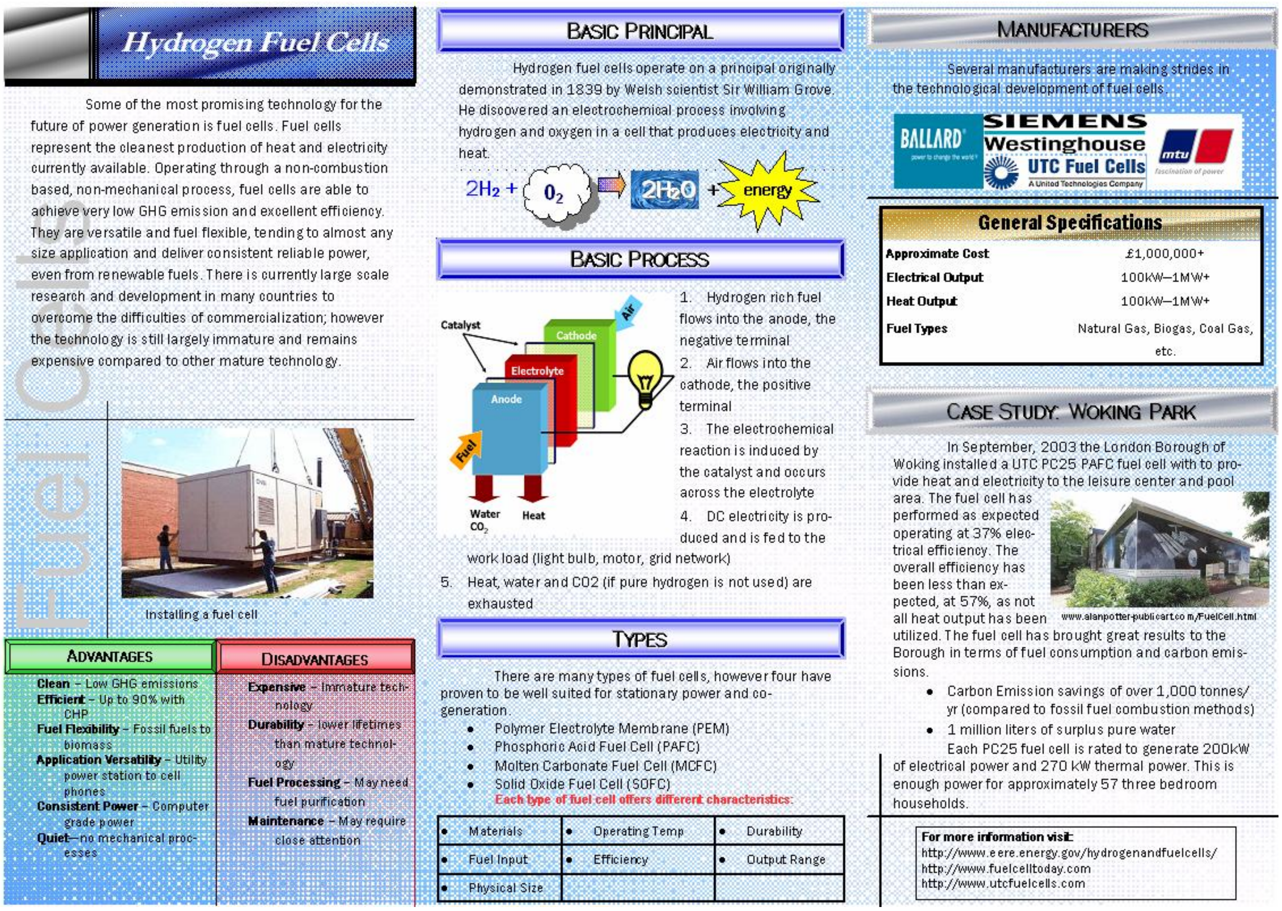

Figure 25: *Progressive Alternative Technologies* - Hydrogen Fuel Cells Handout

Because the principles behind pyrolysis and anaerobic digestion are slightly different from that of CHP and hydrogen fuel cells, a slightly altered format is used to highlight key aspects of these technologies. In addition to the previous stated list, the following information is included in the explanation of each of these technologies:

- A list of suitable and unsuitable waste material
- A list of the by-products and their potential use

As for hydrogen fuel cells and CHP, a number of the same pictures from the PowerPoint are used to visually explain the topics and enhance the look and appeal of the handout. Figure 26 contains the page created for anaerobic digestion.

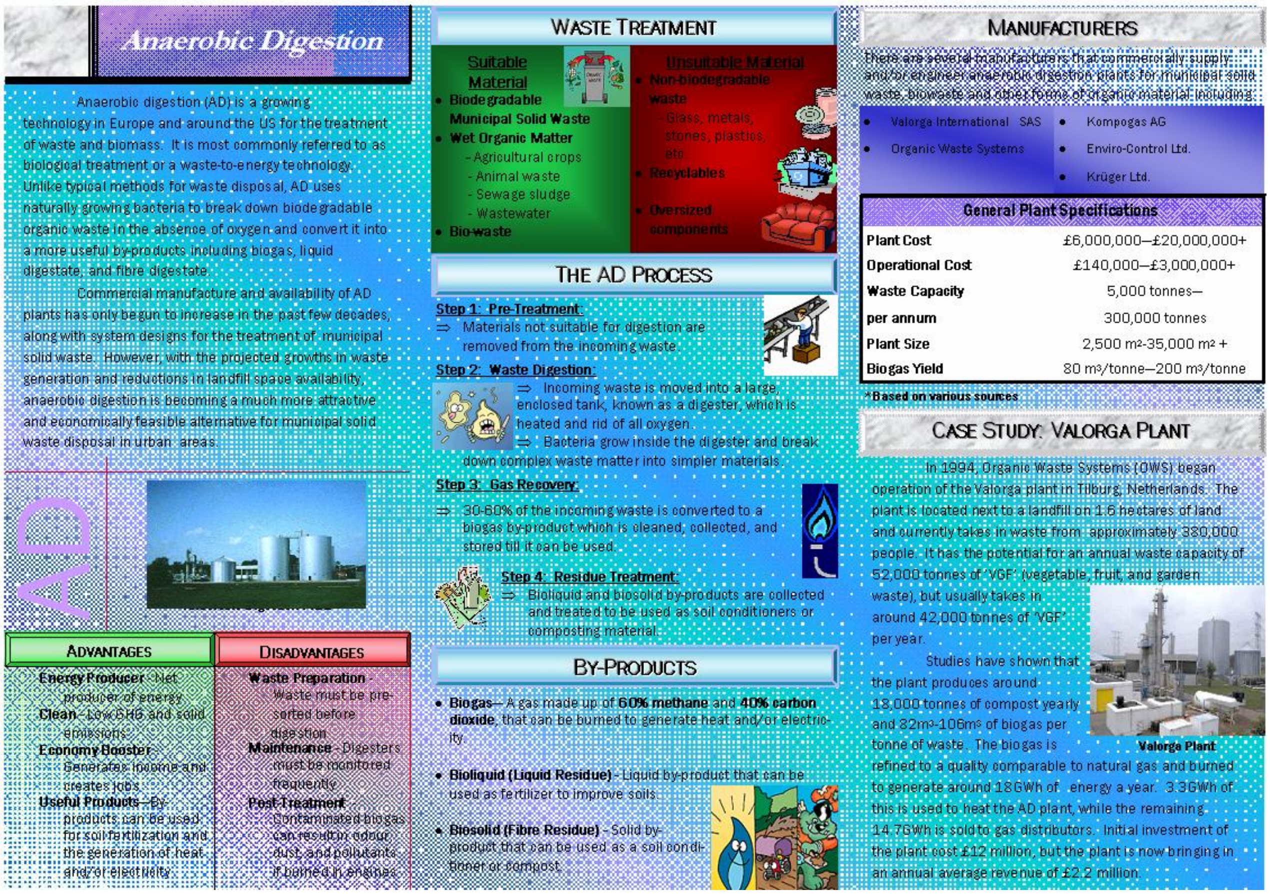

Figure 26: *Progressive Alternative Technologies* - Anaerobic Digestion Handout

A full version of *Progressive Alternative Technologies* can be found at the end of the report as a stand alone document following appendix F. This report will also be made available online at the London Borough of Merton's website.

4.3.3 Version 3: Alternative Energy Technologies: High Tech Solutions for Urban Carbon Reduction

Alternative Energy Technologies: High Tech Solutions for Urban Carbon Reduction is a technical report that was created as a potential educational resource for students, policymakers, and others with a general understanding of each technology who desired more detailed and in-depth information. This report was based primarily on our initial research and was designed in Microsoft Word much like a typical research report. It includes information on district heat and power, combined heat and power, hydrogen fuel cells, pyrolysis, and anaerobic digestion. It focuses specifically on the technical detail of how each technology work, the advantages and disadvantages of each, and includes general case studies. There are very few pictures beyond full schematics of the technologies and little information regarding available equipment.

The report is broken down by section and includes a title page, detailed introduction page, a table of contents, sections on each of the technologies with brief introductions at the beginning of each, and a final list of resources. The text is thorough and comprehensive and requires at least a general knowledge of the technology for a full understanding. This report will be available as a literary source in Merton council and can potentially be included on the London Borough of Merton's website. A final draft of the report can be found as a stand alone document following *Progressive Technologies for a Greener Future*.

Chapter 5: Conclusions

The London Borough of Merton is at the forefront of reducing energy consumption and carbon emissions. The proposed reduction strategy is to implement a DHP network powered by CHP units and other alternative technologies. To realize this strategy and begin taking the next steps in the developmental process, it is vital for key decision makers and planners in Merton to understand the available options. However, a problem which Merton faces today is a lack of effective communication tools that help planners to prepare for the implementation of future equipment and politicians to understand the possibilities of new technologies and share in the vision to make commitments for further development. Engineering and consulting firms have formulated detailed technical reports and feasibility studies on the possibility of implementing new, more efficient technologies. However, many of these reports do not communicate well to all audiences, including many policymakers who may not have a technical background or understanding. This creates a barrier between the possibility of implementing new technologies and actual implementation, which ultimately rests in the hands of policymakers in Merton council.

The purpose of our project was to bridge this communication gap by finding a way to explain the fundamentals of new alternative energy technologies, available units, and associated costs and benefits in an easy and clear way which all policymakers and potential audiences could understand. Through extensive research we were able to gather enough information and knowledge to put together three potential educational resources and communication tools for policymakers in the Borough of Merton and other municipalities of greater London. Our guides were designed to tend to a range of audiences and learning styles and to cover all aspects of communication including visual presentation, internet accessibility, and literature.

All three versions were based on a foundation of education and communication. We included varying levels of detail and depth on how each technology works and what its purpose is in order to provide an educational resource for a wide range of audiences. Additional information regarding specifications on available equipment was added as a communication tool in order to convey actual examples, feasibility, and the potential effects which these technologies could have on a community, especially in regards to finances. In effect, we conveyed many of the same ideas typically provided by engineers in feasibility studies in a more concise and easily accessible manner which could potentially address all types of readers and backgrounds.

We expect that at least one of these three guides or a combination of each will help to be a turning point in the decision to begin the implementation of CHP systems within the next few years, and will encourage the possibility of pyrolysis, anaerobic digestion, and/or hydrogen fuel cells within the next 5-15 years. Merton is at the forefront of the localization of power generation, and in the case that implementation of these technologies does occur, will represent a sustainable energy model for neighboring boroughs and greater London. We anticipate that our work will contribute to these efforts as well as provide a replicable tool and model for other future Energy Action Areas and neighboring boroughs who intend to investigate the possibilities of renewable and cleaner, more efficient technologies.

There are numerous possibilities for renewable energy technologies in the world today, and likely more will arise in the future. For the purposes of this project, we primarily focused our research on the four main technologies which Merton outlined as potentials for implementation in Mitcham and would be most beneficial to the problems currently facing the borough of Merton. We were unable to touch upon all available technologies, but in the future, we hope that the guides which we produce today will be a catalyst for future self-directed research and development. We look forward to the prospect of our work as a government communication tool and a prospective educational resource for other students and interested audiences. We hope our contribution of a replicable communication model will have a rippling effect through Merton and propagate insight to London, Britain and beyond.

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Appendix A: Manufacturer Contact Info

Manufacturer Contacts (Phone: +44 unless specified)

Company	Technology	Contactee	Email	Phone	Location	Website
ABB CHP Limited	CHP	Terry Coldwell Sandy Honeyman	terry.coldwell@gb.abb.com sandy.honeyman@gb.abb.com	01785 825 964	Staffordshire	www.abb.com
Aircogen CHP Solutions	CHP	Joe Knowles	Joe.Knowles@aircogen.co.uk	01733 292 450	Peterborough	www.aircogen.co.uk
ATCO Power Generation Limited	CHP	Ian Smith	info@atcopower.co.uk	02072 223 892	London	www.atcopower.com
Baxi Group Ltd.	mini-CHP	Mr. Ian Stares	N/A	01332 524 800	Derby	www.baxigroup.com
Clarke-Energy	CHP	Mr. Ian Hill	info@clark-energy.com	01515 464 446	Liverpool	www.clark-energy.co.uk
Cogenco Ltd.	CHP	Mr. Dudley McDonald	info@cogenco.co.uk	01403 272 270	West Sussex	www.cogenco.co.uk
Compact Power	Pyrolysis	N/A	info@compactpower.co.uk	017 980 2900	Bristol	www.compactpower.co.uk
ENER-G Combined Power	small scale CHP	Jason Clark	chp@energ.co.uk	01617 457 450	Manchester	www.energ.co.uk
Siemens Power Generation	CHP	Peter Southworth	peter.southworth@siemens.com	01344 396 000	Berkshire	www.siemens.co.uk
WasteGen UK, Ltd	Pyrolysis + Power Generation (MERPS)	N/A	N/A	N/A	N/A	www.wastegen.com

Appendix B: Pyrolysis Manufacturer E-mail

To Whom It May Concern:

My name is Danielle Sorenson, and I am a student from Worcester Polytechnic Institute in Massachusetts, USA. I am currently working with a group of 2 other students on a project with the Merton Council planning and regeneration department. Merton is trying to implement a district heat and power network in Mitcham run by a series of combined heat and power units. Mitcham is a small town in the Borough of Merton that has been established by the Mayor of London as one of four energy action areas, small regeneration areas which are working to reduce carbon emissions and energy consumption. In particular, they are considering the implementation of waste-to-energy technologies such as pyrolysis and/or anaerobic digestion which will help to reduce municipal solid waste transport to landfills and possibly problems with sewage sludge. My team and I are trying to devise a potential implementation scheme for these units. We are working right now to contact various manufacturers and collect information about the units which they provide.

I have done some research on your company already, and was wondering if you could possibly help us out. I am looking to gain some data regarding the plants your company supplies. I tried calling earlier today, but I was unable to reach anyone. Specifically, I am looking for the following information on a range of the plants your company has available:

- Plant type (Model)
- Cost (Capital, Operational, Installation, etc.)
- Waste Processing capability (Waste capacity)
- Typical waste streams/utilization
- Physical plant size
- Amount of land space required by the plant
- Net electrical output
- Usable heat output
- Any possible fuel output??
- Maintenance Plans

We are still in the initial planning stages of our project, so we are just trying to gather data on a broad range of units so that we may provide Merton with some possible options. We would greatly appreciate any information which you could provide us with.

You can e-mail me personally with the information at dnsoren@wpi.edu or you can e-mail my entire project group at mertonenergy-d06@wpi.edu. Thank you very much for your time and I hope to hear from you again soon.

Sincerely,

Danielle Sorenson

Appendix C: Anaerobic Digestion Manufacturer E-mail

To Whom It May Concern:

I'm not sure if I contacted the right person, but I was hoping you could help me out or direct me to someone who could. My name is Danielle Sorenson, and I am a student from Worcester Polytechnic Institute in Massachusetts, USA. I am currently working with a group of 2 other students on a project with the Merton Council planning and regeneration department. Merton is trying to implement a district heat and power network in Mitcham run by a series of combined heat and power units. Mitcham is a small town in the Borough of Merton that has been established by the Mayor of London as one of four energy action areas, small regeneration areas which are working to reduce carbon emissions and energy consumption. In particular, they are considering the implementation of waste-to-energy technologies such as pyrolysis and/or anaerobic digestion, which will be used in combination with CHP units and help to reduce municipal solid waste transport to landfills and possibly problems with sewage sludge. My team and I are trying to devise a potential implementation scheme for these units. We are working right now to contact various manufacturers and collect information about the units which they provide.

I have done some research on your company already, and was wondering if you could possibly help us out. I am looking to gain some data regarding the plants your company supplies. Specifically, I am looking for the following information on a range of the plants your company has available:

- Plant type (Model)
- Cost (Capital, Operational, Installation, etc.)
- Waste Processing capability (Waste capacity)
- Feedstock
- Physical plant size
- Amount of land space required by the plant
- Electricity production
- Biogas production (Any other fuel output??)
- Maintenance Plans

We are still in the initial planning stages of our project, so we are just trying to gather basic data on a broad range of plants so that we may provide Merton with some possible options. I know you already have a good amount of this information available on your website, but are we are particularly interested in the plant and installation cost. We would greatly appreciate any information which you could provide us with.

You can e-mail me personally with the information at dnsoren@wpi.edu or you can e-mail my entire project group at mertonenergy-d06@wpi.edu. Thank you very much for your time and I hope to hear from you again soon.

Sincerely,

Danielle Sorenson

Appendix D: CHP Correspondence

D-1: Aircogen Correspondence

Aircogen CHP Solutions

Nimbus Range - (Packaged Combined Heat and Power Systems)

Product Code:	Gross Power Output kWe	Hot Water Output kWth	Chilled Water Output (optional) kW	Fuel Use (HHV) kW	Electrical Efficiency %	Thermal Efficiency %	CHP Total Efficiency %
Nimbus 63L	63	120	78	223	28%	54%	82%
Nimbus 104L	104	127	83	310	34%	41%	74%
Nimbus 200L	200	233	151	592	34%	39%	73%
Nimbus 238L	238	359	233	734	32%	49%	81%
Nimbus 309L	309	405	263	946	33%	43%	75%
Nimbus 415L	415	549	357	1273	33%	43%	76%
Nimbus 508L	508	641	417	1481	34%	43%	78%
Nimbus 607L	607	796	517	1870	32%	43%	75%
Nimbus 770L	770	953	619	2275	34%	42%	76%
Nimbus 815L	815	1145	744	2510	32%	46%	78%
Nimbus 1030L	1030	1178	766	3033	34%	39%	73%
Nimbus 1160L	1160	1441	937	3271	35%	44%	80%
Nimbus 1364L	1364	1550	1008	3732	37%	42%	78%
Nimbus 1575L	1575	1647	1071	4456	35%	37%	72%
Nimbus 1760L	1760	1821	1184	4979	35%	37%	72%
Nimbus 1942L	1942	2035	1323	5201	37%	39%	76%
Nimbus 2000L	2000	2036	1323	5361	37%	38%	75%

Notes:

1) Each Nimbus package incorporates the following features as standard:
- Thermal output as hot water at 82C Flow 71C Return.
- Dry air cooler for intercooler heat dissipation if required (loose shipped).
- Extended oil lubrication system for prolonged oil service intervals and improved engine life.*
- Power Delivery Control System (PDC) for mains monitoring, protection and synchronisation functions.*
- PLC control system complete with remote monitoring, control and reporting functions.*
- Comprehensive works test including full load operation.
- Acoustic enclosure constructed from self supporting and fully de-mountable panelling system.

* Excludes Nimbus 63L

2) Package Options Include:
- Terminal points for connection of existing or third party heat dissipation equipment.
- Dry air cooler to be installed locally or package mounted. Enables fully automated and modulating heat dissipation.
- All weather enclosure with drainage fittings.

3) Nimbus Trigeneration and CCP units consist of a Nimbus package, close coupled to a packaged single effect absorption chiller. Heat rejection equipment is offered as an optional extra for location adjacent to the unit. The complete system is controlled via a single PLC with all features as listed above for 'Nimbus'. Packages are equipped to modulate between hot water and chilled water output in accordance with site demand (subject to specific turndown capability). See individual Data Sheets for detailed unit data and associated tolerences.

Nimbus packages can also be configured for Medium Temperature Hot Water, Steam or Heated Air Output, to request specific unit data email: techsupport@aircogen.com

Aircogen CHP Solutions

Nimbus Range - (Packaged Combined Heat and Power Systems)

Product Code:	Gross Power Output kWe	Hot Water Output kWth	Length mm	Width mm	Height mm
Nimbus 63	63	120	2300	1400	2100
Nimbus 104	104	127	3500	1750	2100
Nimbus 200	200	233	3850	1750	2200
Nimbus 238	238	359	4200	1750	2200
Nimbus 309	309	405	4700	2450	2400
Nimbus 415	415	549	5050	2450	2400
Nimbus 508	508	641	6300	2800	3150
Nimbus 607	607	796	7000	3150	3500
Nimbus 770	770	953	8050	3500	3850
Nimbus 815	815	1145	8050	2800	3850
Nimbus 1030	1030	1178	8400	3850	3850
Nimbus 1160	1160	1441	8750	3500	3850
Nimbus 1364	1364	1550	8750	3500	3850
Nimbus 1575	1575	1647	8750	3500	4200
Nimbus 1760	1760	1821	9100	3500	4200
Nimbus 1942	1942	2035	10150	3850	4200
Nimbus 2000	2000	2036	10150	3850	4200

Notes:

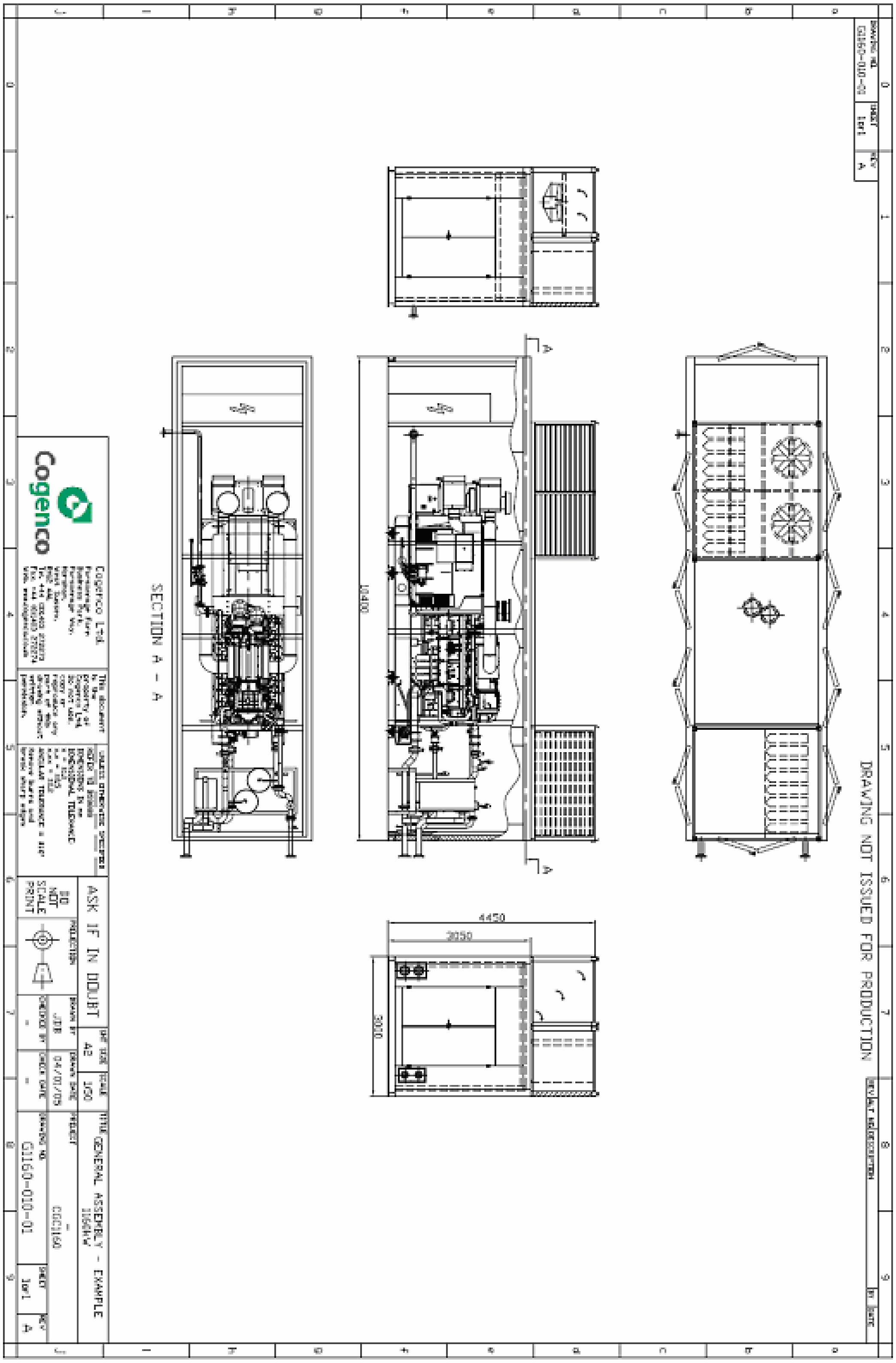
Nominal Dimentions Only

1) Each Nimbus package incorporates the following features as standard:
   - Thermal output as hot water at 82C Flow 71C Return.
   - Dry air cooler for intercooler heat dissipation if required (loose shipped).
   - Extended oil lubrication system for prolonged oil service intervals and improved engine life.*
   - Power Delivery Control System (PDC) for mains monitoring, protection and synchronisation functions.*
   - PLC control system complete with remote monitoring, control and reporting functions.*
   - Comprehensive works test including full load operation.
   - Acoustic enclosure constructed from self supporting and fully de-mountable paneling system.

   * Excludes Nimbus 63L

2) Package Options Include:
   - Terminal points for connection of existing or third party heat dissipation equipment.
   - Dry air cooler to be installed locally or package mounted. Enables fully automated and modulating heat dissipation.
   - All weather enclosure with drainage fittings.

D-2: Cogenco Correspondence



COGENCO DATA SHEET

CGC-1160-L-NGUK-50

Low Temperature UK Natural Gas

Cogenco

TECHNICAL SPECIFICATION

Cogenco Identification:	CGC-1160-L-NGUK-50	Compression ratio:	12.0:1
Engine Type:	Cummins QSK 60G (16.0 bar)	Engine Speed (rpm):	1500
Generator Type:	Cummins	Lambda:	1.74
Configuration:	16 Cylinder V	Power Factor:	1.00
Exhaust Manifold:	Water Cooled	Barometric pressure (kPa):	100
Cylinder bore (mm):	159	Exhaust Gas Temperature after H/E (°C):	120
Piston stroke (mm):	190	Ambient Temperature (°C):	25
Engine swept volume (L):	60.3	Net Heating Value (kJ/Nm3):	34710
Mean effective pressure (bar):	16.0	Emission level at 5% O2 (mg/Nm3):	

PERFORMANCE AND EFFICIENCY

PERFORMANCE AND EFFICIENCY		100%		75%		50%	
Fuel input:	kW	2974	%	2297	%	1630	%
Mechanical output:	kW	1207	40.6	906	39.4	604	37.1
Electrical output:	kW	**1160**	**39.0**	**871**	**37.9**	**580**	**35.6**
Heat output from jacket water and oil:	kW	718	24.1	544	23.7	399	24.5
Heat output from exhaust gases (120°C):	kW	724	24.3	584	25.4	423	26.0
Total useable heat output:	kW	**1442**	**48.5**	**1128**	**49.1**	**822**	**50.4**
Total useable energy:	kW	**2602**	**87.5**	**1999**	**87.0**	**1402**	**86.0**
Intercooler heat output:	kW	72	2.4	62	2.7	52	3.2
Radiated and unaccounted for heat:	kW	125	4.2	106	4.6	87	5.3

TEMPERATURES AND FLOWS

Fuel mass flow:	kg/hr	238.1	183.9	130.5
Fuel volume flow:	Nm3/hr	308.5	238.2	169
Ventilation air flow:	Nm3/hr	40100	40100	40100
Combustion air mass flow:	kg/hr	6535	4950	3435
Combustion air volume flow:	Nm3/hr	5750	4356	3023
Exhaust gas mass flow (wet):	kg/hr	6774	5134	3566
Exhaust gas volume flow (wet):	Nm3/hr	6059	4301	2986
Exhaust gas volume flow (wet) at 120 degC:	Nm3/hr	7541	5716	3970
Jacket water flow:	m3/hr	70	70	70
Intercooler water flow minimum:	m3/hr	23	23	23
Secondary water flow minimum:	m3/hr	130	130	130
Maximum return water inlet temperature:	°C	80	80	80
Secondary water outlet temperature:	°C	89.8	87.7	85.6
Maximum intercooler water inlet temperature:	°C	50	50	50
Intercooler water outlet temperature:	°C	52.9	52.5	52.1
Exhaust gas temperature before cooler:	°C	469	491	508

WEIGHTS AND DIMENSIONS

Weight - dry	kg	15000
Weight - wet	kg	15500
Engine/generator only excluding heat skid		
Length	mm	4890
Width	mm	2240
Height	mm	2074

Cogenco Limited
Parsonage Farm Business Park
Parsonage Way
HORSHAM West Sussex
United Kingdom RH12 4AL
Tel: +44 (0)1403 272270
Fax: +44 (0(1403 272274
www.cogenco.co.uk
sales@cogenco.co.uk

Due to continuous product development, Cogenco Limited reserve the right to change these specifications without notice.
Tolerances: Energy input +/- 5%, Power output +/- 3%, Exhaust flow and temperature +/-5%. Definitions of ratings to ISO 3046

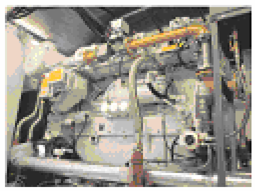
Issue/rev: rev 1
Date: 22/12/2004

D-3: Ener-G Correspondence

ENER·G 375

TECHNICAL DATA - ENER·G 375

GENERAL DESCRIPTION



- Fuel Type:	Natural Gas
- Electrical Output:	377 kWe
- Heat Output @81^{0}C	428 kWh
- Fuel Input LHV:	978 kWg
- Fuel Input HHV:	1082 kWg
- Min Gas Pressure mbar:	20
- Max. Gas Pressure mbar:	60
- Max Return Water Temp:	80^{0}C
- Min Methane No:	75

PRIME MOVER

- Type:	Reciprocating Engine
- Combustion Cycle:	4 stroke spark ignition
- Cylinders:	6 inline
- Speed:	1500
- Aspiration:	Turbocharged
- Intercooler:	45^{0}C
- Acoustic Enclosure	75 dBA @ 1m std. (internal)

GENERATOR:

- Type:	Synchronous
- Generator Capacity:	630 KVA
- Frequency:	50Hz
- Voltage:	400 V
- Full Load Current:	607 A
- Efficiency:	96.10%

HEAT RECOVERY SYSTEM
(Integral to Unit)

- Fully closed primary water circuit
- Exhaust gas heat exchanger in primary circuit
- PHE between primary & secondary circuits
- Primary water pump integral
- Secondary water pump loose for external fitting
- Auto heat output modulation

CONTROL & PROTECTION:

- On board computer control, protection and monitoring
- Engine stop/start, synchronising, modulation
- Mechanical, electrical and thermal protection
- 70+ parameters monitored, historical data recorded
- 2 way communication between unit and Head Office

OPTIONAL / ADDITIONAL EQUIPMENT:

- External acoustic container packages
- Internal acoustic enclosure upgrades
- BEMS interface card
- Gas / fire detection systems
- Island (emergency genset) operation
- Heat and gas metering
- Export control panel
- Heat rejection equipment / controls
- Exhaust silencers (industrial & residential grade)
- Catalytic converter's for very low emissions
- Anti-vibration support platforms for special applications
- CHP absorption chiller packages
- Packaged plant rooms including CHP
- Gas generation packages (no Heat Recovery)

- Fuel consumption figures show fuel figures at lower & higher calorific values.
- Energy quantities subject to reduction when modulating in response to external conditions.
- We reserve the right to alter the engine type, at any time, to meet the system specifications.
- Electrical output is based on output at the generator terminals at a power factor of 0.9
- Performance figures are subject to original engine manufacturers tolerances.
- Technical Datasheets are subject to change, without notice, due to ongoing R&D.
- ENER·G Combined Power Limited are part of the ENER·G Group

April [illegible]

ENER·G House, Daniel Adamson Road, Manchester M50 1DT - T: 00 44 161 745 7450 E: chp@energ.co.uk W: www.energ.co.uk

Appendix E: CHP Unit Comparison Spreadsheet

Reciprocating Engine CHP Comparison — * 17 hours per day

Company	Cogenco	Cogenco	Cogenco	Cogenco	Cogenco
Model	CGC-0082-L-NGUK-50	CGC-0130-L-NGUK-51	CGC-0167-L-NGUK-52	CGC-0237-L-NGUK-53	CGC-380-L-NGUK-54
Type	Gas Engine	Gas Engine	Gas Engine	Gas Engine	Gas Engine
Engine Manufacturer	M.A.N.	M.A.N.	M.A.N.	M.A.N.	M.A.N.
Electrical Power (KW)	82	130	167	237	380
Thermal Power (KW)	132	201	260	359	500
Electrical Efficiency	33.1%	34.4%	34.2%	35.5%	37.0%
Overall Efficiency	86.30%	87.60%	87.30%	89.40%	85.80%
Capital Cost	62,000	65,374	80,000	86,338	122,682
Installation Cost	16,400	26,000	33,400	47,400	95,000
Fuel	Natural Gas propane diesel; biogas	Natural Gas propane diesel; biogas	Natural Gas propane diesel; biogas	Natural Gas propane diesel; biogas	Natural Gas propane diesel; biogas
Comments	Turn-key co-generation systems with full service options available	Turn-key co-generation systems with full service options available	Turn-key co-generation systems with full service options available	Turn-key co-generation systems with full service options available	Turn-key co-generation systems with full service options available
Website	www.cogenco.co.uk	www.cogenco.co.uk	www.cogenco.co.uk	www.cogenco.co.uk	www.cogenco.co.uk
Maintenance (3 year)	5,000	5,158	6,800	6,358	10,243
Maintenance (5 year)	6,700	6,738	8,890	8,890	13,372
Maintenance (10 year)	7,500	7,513	10,146	10,146	16,365
Engine Type	086 GV NX 86 (5.8 bar)	MAN E2876 E302 (9.4 ba	MAN E2842 E (6.4 bar)	MAN E2842 E312 (9.1 ba	MAN E2842 LE 312 (14.6
Generator Type	ECO38-1S	ECO38-1S	Newage HC434D	ECO38-3L	ECO40-1L/4
Barometric Pressure (kPa)	101.32	100	100	100	100
Length (mm)	3300	3300	4050	4050	4060
Width (mm)	1250	1250	1500	1500	1510
Height (mm)	2610	2610	2860	2860	2860

Cogenco	Cogenco	Cogenco	Cogenco	AirCogen	AirCogen	AirCogen	AirCogen
CGC-725-L-NGUK-	CGC-1160-L-	CGC-1760-L-NGUK-57	CGC-2000-L-NGUK-	Nimbus 63L	Nimbus 104L	Nimbus 200L	Nimbus 238L
Gas Engine	Gas Engine	Gas Engine	Gas Engine	Gas Engine	Gas Engine	Gas Engine	Gas Engine
Caterpillar	Cummins	Cummins	Cummins				
725	1160	1760	2000	63	104	200	238
1019	1442	1821	2354	120	127	233	359
35.2%	39.0%	38.9%	39.0%	35.0%	31.0%	31.0%	36.0%
84.70%	87.50%	84.30%	85.00%	82%	74%	73%	81%
261,617	347,980	486,424	540,424	65,000	75,000	120,000	130,000
181,250	290,000	440,000	480,000	15,000	25,000	50,000	50,000
Natural Gas propane diesel; biogas	Natural Gas propane diesel; biogas	Natural Gas propane diesel; biogas	Natural Gas propane diesel; biogas	Natural Gas propane diesel; biogas	Natural Gas propane diesel; biogas	Natural Gas propane diesel; biogas	Natural Gas propane diesel; biogas
Turn-key co-generation systems with full	Turn-key co-generation systems with full	Turn-key co-generation systems with full service options available	Turn-key co-generation systems with full service	Turnkey CHP	Turnkey CHP	Turnkey CHP	Turnkey CHP
www.cogenco.co.uk	www.cogenco.co.uk	www.cogenco.co.uk	www.cogenco.co.uk	www.aircogen.co.uk	www.aircogen.co.uk	www.aircogen.co.uk	www.aircogen.co.uk
13,478	30,006	21,607	21,607	5,000	5,000	6,800	6,800
20,651	25,579	20,927	20,927	6,700	6,700	8,890	8,890
22,936	31,586	36,465	36,465	7,500	7,500	10,146	10,146
Caterpillar G3512 LE (	Cummins QSK 60G (1	Cummins QSV 916 (16.1 bar)					
G3512/695	Cummins	LV 824C					
100	100	100					
4330	4890	5670		2300	3500	3850	4200
2160	2240	1720		1400	1750	1750	1750
2063	2074	1660		2100	2100	2200	2200

AirCogen	AirCogen	AirCogen	AirCogen	AirCogen	AirCogen	AirCogen	AirCogen	AirCogen	AirCogen
Nimbus 309L	Nimbus 415L	Nimbus 508L	Nimbus 607L	Nimbus 770L	Nimbus 815L	Nimbus 1030L	Nimbus 1160L	Nimbus 1364L	Nimbus 1575L
Gas Engine	Gas Engine	Gas Engine	Gas Engine	Gas Engine	Gas Engine	Gas Engine	Gas Engine	Gas Engine	Gas Engine
309	415	508	607	770	815	1030	1160	1364	1575
405	549	641	746	953	1145	1178	1441	1550	1647
32.0%	32.0%	36.0%	33.0%	33.0%	33.0%	35.0%	35.0%	33.0%	33.0%
75%	76%	78%	75%	76%	78%	73%	80%	78%	72%
120,000	230,000	270,000	310,000	350,000	380,000	420,000	445,000	470,000	520,000
95,000	100,000	100,000	100,000	100,000	150,000	150,000	150,000	150,000	150,000
Natural Gas propane diesel; biogas	Natural Gas propane diesel; biogas	Natural Gas propane diesel; biogas	Natural Gas propane diesel; biogas	Natural Gas propane diesel; biogas	Natural Gas propane diesel; biogas	Natural Gas propane diesel; biogas	Natural Gas propane diesel; biogas	Natural Gas propane diesel; biogas	Natural Gas propane diesel; biogas
Turnkey CHP	Turnkey CHP	Turnkey CHP	Turnkey CHP	Turnkey CHP	Turnkey CHP	Turnkey CHP	Turnkey CHP	Turnkey CHP	Turnkey CHP
www.aircogen.co.uk	www.aircogen.co.uk	www.aircogen.co.uk	www.aircogen.co.uk	www.aircogen.co.uk	www.aircogen.co.uk	www.aircogen.co.uk	www.aircogen.co.uk	www.aircogen.co.uk	www.aircogen.co.uk
10,243	10,243	10,243	13,478	13,478	15,000	15,000	15,000	15,000	17,000
13,372	13,372	13,372	20,651	20,651	22,000	22,000	22,000	22,000	25,000
16,365	16,365	16,365	22,936	22,936	24,000	24,000	24,000	24,000	30,000
4700	5050	6300	7000	8050	8050	8400	8750	8750	8750
2450	2450	2800	3150	2800	2800	3850	3500	3500	3500
2400	2400	3150	3500	3850	3850	3850	3850	3850	4200

AirCogen	AirCogen	AirCogen	ENER-G	ENER-G	ENER-G	ENER-G	ENER-G	ENER-G
Nimbus 1760L	Nimbus 1942L	Nimbus 2000L	E150	E230	E375	E1150	E1600	E2000
Gas Engine	Gas Engine	Gas Engine	Gas Engine	Gas Engine	Gas Engine	Gas Engine	Gas Engine	Gas Engine
			Mercedes Benz	Mercedes Benz	Perkins	Caterpillar	Caterpillar	Caterpillar
1760	1942	2000	150	228	377	1150	1600	2000
1821	2035	2036	231	358	428	1428	1634	2213
36.0%	36.0%	37.0%	31.6%	31.7%	34.8%	33.9%	37.0%	35.7%
72%	76%	75%	75%	75%	75%	75%	75%	75%
620,000	720,000	820,000	95,000	116,000	180,000	495,000	600,000	750,000
200,000	200,000	200,000	0	0	0	0	0	0
Natural Gas propane diesel; biogas	Natural Gas propane diesel; biogas	Natural Gas propane diesel; biogas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas
Turnkey CHP	Turnkey CHP	Turnkey CHP	Turnkey CHP	Turnkey CHP	Turnkey CHP	Turnkey CHP	Turnkey CHP	Turnkey CHP
www.aircogen.co.uk	www.aircogen.co.uk	www.aircogen.co.uk	www.energ.co.uk	www.energ.co.uk	www.energ.co.uk	www.energ.co.uk	www.energ.co.uk	www.energ.co.uk
21,607	21,607	21,607	6,500	7,000	13,500	18,500	18,500	21,500
20,927	20,927	20,927	8,000	9,000	17,000	26,000	26,000	30,000
36,465	36,465	36,465	10,500	12,000	22,000	29,000	29,000	36,000
9100	10150	10150	3500	4000	4266	6500	6500	6500
3500	3850	3850	1400	1450	2100	3000	3000	3000
4200	4200	4200	1940	2120	2750	3365	3365	3365

Clarke-Energy	Clarke-Energy	Clarke-Energy	Clarke-Energy	Clarke-Energy	Clarke-Energy	Clarke-Energy
JMS208GS-NL	JMS312GS-NL	JMS312GS-NL	JMS316GS-NL	JMS320GS-NL	JMS420GS-NL	JMS612GS-NL
Gas Engine	Gas Engine	Gas Engine	Gas Engine	Gas Engine	Gas Engine	Gas Engine
GE	GE	GE	GE	GE	GE	GE
330	526	625	836	1065	1416	1644
361	633	746	997	1197	1505	1730
38.7%	39.2%	39.8%	40.0%	40.9%	42.4%	42.4%
81%	86%	87.42%	87.64%	86.77%	87.52%	87.02%
285,000	354,000	404,500	477,000	517,500	653,000	810,500
0	0	0	0	0	0	0
Natural Gas Biogas	Natural Gas Biogas	Natural Gas Biogas	Natural Gas Biogas	Natural Gas Biogas	Natural Gas Biogas	Natural Gas Biogas
Turnkey CHP	Turnkey CHP	Turnkey CHP	Turnkey CHP	Turnkey CHP	Turnkey CHP	Turnkey CHP
www.clarke-energy.co.uk	www.clarke-energy.co.uk	www.clarke-energy.co.uk	www.clarke-energy.co.uk	www.clarke-energy.co.uk	www.clarke-energy.co.uk	www.clarke-energy.co.uk
10,000	10,000	13,000	13,000	21,500	21,500	30,000
13,000	13,000	20,000	20,000	21,000	21,000	25,000
16,000	16,000	22,000	22,000	36,500	36,500	31,000
GE	GE	GE	GE	GE	GE	GE

Appendix F: Anaerobic Digestion Correspondence

F-1: Organic Waste Systems Correspondence

OWS
Organic Waste Systems

DRANCO REFERENCE LIST

I. Demonstration plants

1. Gent, Belgium	
Substrate:	mixed garbage and biowaste
Volume:	60 m³
Year:	1984

2. Bogor, Indonesia	
Substrate:	market waste
Volume:	30 m³
Year:	1986

3. Florida, USA	
Substrate:	mixed garbage
Volume:	1 m³
Year:	1989

4. Graz, Austria	
Substrate:	mixed garbage
Volume:	5 m³
Year:	1990

5. Kagoshima, Japan	
Substrate:	garbage and manure
Volume:	30 m³
Year:	1998

6. Yaku Island, Japan	
Substrate:	biowaste and manure
Volume:	30 m³
Year:	2001

7. Graincourt les Havrincourt, France	
Substrate:	grey waste and miscellaneous
Volume:	15 m³
Year:	2004

II. Full-scale plants

1. *Brecht I*

Location:	Brecht, Belgium (near Antwerp)
Project:	DRANCO-plant for the anaerobic digestion of biowaste and waste paper
Capacity:	20,000 ton/year
Start-up:	July 1992
Realization time:	March 1991 - June 1992
Client:	IGEAN Address: Doornaardstraat 60, B-2160 Wommelgem Contact: Mr. P. Magielse Tel.: +32 3 330 19 20
Supply of OWS:	Engineering and construction of the entire plant. OWS was also responsible for the operation of the plant.
Contract:	BOT, 100% OWS

2. *Salzburg*

Location:	Bergheim-Siggerwiesen, Austria (near Salzburg)
Project:	DRANCO-plant for the anaerobic digestion of biowaste
Capacity:	20,000 ton/year
Start-up:	December 1993
Realization time:	16 months
Client:	Salzburger Abfallbeseitigung Gesellschaft (SAB) Address: Aupoint 15, A-5101 Bergheim (Siggerwiesen) Contact: Mr. Dr. K. Steger Tel.: +43 662 469 490
Supply of OWS:	Engineering and delivery of the anaerobic digestion part
Contract:	Subcontractor

3. *Bassum*

Location:	Bassum, Germany
Project:	DRANCO-plant for the anaerobic digestion of grey waste
Capacity:	13,500 ton/year
Start-up:	June 1997
Realization time:	May 1996 - June 1997
Client:	Abfallwirtschaftgesellschaft mbH (AWG) Address: Klövenhausen 20, D-27211 Bassum Contact: Mr. A. Nieweler Tel.: +49 4241 801 105
Supply of OWS:	Engineering and construction of the anaerobic plant
Contract:	General contractor

4. *Kaiserslautern*

Location:	Kaiserslautern, Germany
Project:	DRANCO-plant for the anaerobic digestion of grey waste
Capacity:	20,000 ton/year
Start-up:	January 1999
Realization time:	March 1997 - December 1998
Client:	Zweckverband Abfallwirtschaft Kaiserslautern ZAK Address: Kapiteltal, D-67657 Kaiserslautern Contact: Mr. Dr. Kewitz Tel.: +49 631 341 170
Supply of OWS:	Engineering and construction of the entire plant, except for civil works
Contract:	General contractor

5. Villeneuve

Location:	Villeneuve, Switzerland	
Project:	DRANCO-plant for the anaerobic digestion of biowaste	
Capacity:	10,000 ton/year	
Start-up:	February 1999	
Realization time:	January 1998 - February 1999	
Client:	SA Compost Chablais-Riviera Address: Case postale 57, CH-1844 Villeneuve	
Supply of OWS:	Assistance during engineering and start-up of the plant	
Contract:	Subcontractor	

6. Brecht II

Location:	Brecht, Belgium (near Antwerp)	
Project:	DRANCO-plant for the anaerobic digestion of biowaste and waste paper	
Capacity:	50,000 ton/year	
Start-up:	January 2000	
Realization time:	July 1998 - December 1999	
Client:	IGEAN Address: Doornaardstraat 60, B-2160 Wommelgem Contact: Mr. P. Magielse Tel.: +32 3 330 19 20	
Supply of OWS:	Detailed engineering of the entire plant and delivery of key components	
Contract:	Subcontractor	

7. Rome

Location:	Rome, Italy	
Project:	DRANCO-plant for the anaerobic digestion of biowaste	
Capacity:	40,000 ton/year	
Start-up:	July 2003	
Realization time:	June 2002 - June 2003	
Client:	E. GIOVI S.r.l. (group SORAIN CECCHINI) Address: Via Portuense 881, I-00148 Rome Contact: Mr. A. Carrera Tel.: +39 06 2248 51 41	
Supply of OWS:	Engineering and construction of the entire plant, except for civil works	
Contract:	General contractor	

8. Leonberg

Location:	Leonberg, Germany	
Project:	DRANCO-plant for the anaerobic digestion of biowaste	
Capacity:	30,000 ton/year	
Start-up:	December 2004	
Client:	Abfallwirtschaft Landkreis Böblingen Address: Parkstrasse 16, D-71034 Böblingen Contact: Mr. A. Kreidl Tel. : +49 7031 66 32 32	
Supply of OWS:	Engineering and construction of the entire plant	
Contract:	General contractor	

9. Hille (MBA Pohlsche Heide)

Location:	Hille, Germany
Project:	DRANCO-plant for the anaerobic digestion of grey waste and dewatered sludge
Capacity:	38,000 ton/year
Start-up:	January 2005
Client:	AML - Immobilien GmbH Address: Pohlsche Heide 1, D-32479 Hille Contact: Mr. Becker Tel.: +49 5703 509 0
Supply of OWS:	Engineering and construction of the entire plant
Contract:	Subcontractor

10. Terrassa

Location:	Terrassa, Spain
Project:	DRANCO-plant for the anaerobic digestion of biowaste
Capacity:	25,000 ton/year
Start-up:	planned for 2006
Client:	CESPA GR Address: Avda de la Catedral 6-8 1ª planta, E-08002 Barcelona Contact: Mr. J. Marza Tel. : +34 93 247 91 09
Supply of OWS:	Engineering and construction of the entire plant, except for civil works
Contract:	General contractor

11. Münster

Location:	Münster, Germany
Project:	DRANCO-plant for the anaerobic digestion of grey waste and industrial waste
Capacity:	24,000 ton/year
Start-up:	March 2005
Client:	REMONDIS GmbH & Co. KG Address: Zum Heidehof 52, D-48157 Münster Contact: Mr. F. Abbenhaus Tel. : +49 251 207 53 33
Supply of OWS:	Engineering and construction of the entire plant, except for civil works
Contract:	Subcontractor

12. Vitoria

Location:	Vitoria, Spain
Project:	DRANCO-plant for the anaerobic digestion of mixed waste
Capacity:	20,000 ton/year
Start-up:	planned for 2006
Client:	BIOCOMPOST DE ÁLAVA UTE C/ Portal del Rey 20, E-01001 Vitoria – Gasteiz Contact: Mr. F. Azpiri Tel. : +34 945291485
Supply of OWS:	Engineering and construction of the entire plant, except for civil works
Contract:	General contractor

Organic Waste Systems

13. Alicante	
Location:	Alicante, Spain
Project:	DRANCO-plant for the anaerobic digestion of mixed waste
Capacity:	30,000 ton/year
Start-up:	planned for 2007
Client:	UTE PLANTA RESIDUOS ALICANTE Avda Maissonave 3,4°A E-03003 Alicante Contact: Mr. I. Estevan Dols Tel. : +34 9 65146200
Supply of OWS:	Engineering and construction of the entire plant, except for civil works
Contract:	General contractor

OWS

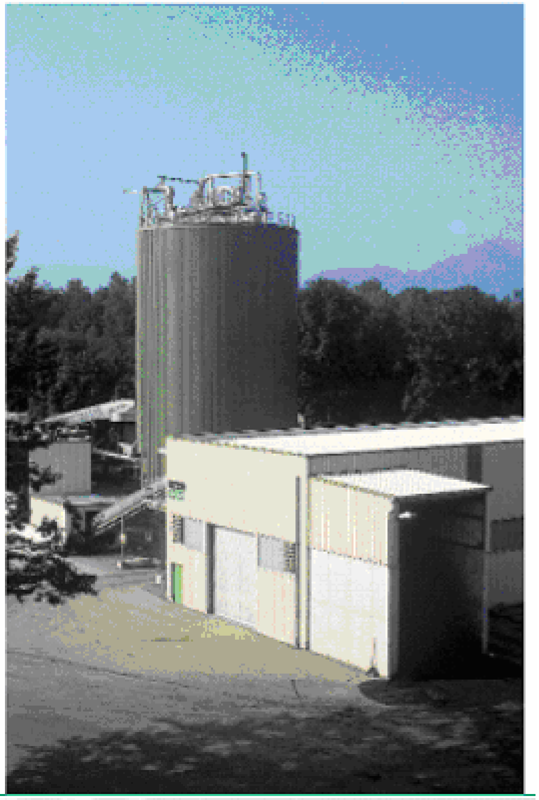
Stock company under Belgian law established in 1988.
Specialized in solid waste treatment:

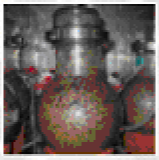
- the DRANCO process: anaerobic digestion of solid waste
- the SORDISEP process: sorting, digestion and separation of solid waste

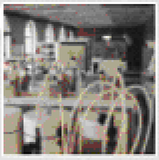
Operating services through wholly owned subsidiary DRANCO NV, and operational and biological assistance for the management of full-scale anaerobic digestion and composting plants.

Laboratory testing and consulting services in the field of waste management and biodegradability of consumer products.

Represented in the U.S.A. through OWS Inc., a wholly owned subsidiary in Dayton, Ohio.







Project Contracting

- turn-key installations
- basic and detailed engineering
- equipment supply
- start-up and operating services
- laboratory and pilot test-runs

Laboratory Testing (GLP-certified)

- biodegradation and compostability tests
- anaerobic digestion studies
- ecotoxicity tests
- compost quality analyses

Operating Services

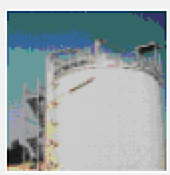
- plant operation through wholly owned subsidiary DRANCO NV
- plant management support for digestion and composting plants
- biological operational assistance
- lab simulation and optimization for full-scale digestion and composting plants

Consulting Services:

- waste composition analyses and modelling
- integrated waste management
- management of organic waste
- developments in composting, anaerobic digestion and biodegradable plastics
- sorting analyses for recyclables, waste paper, waste fractions derived from MSW,...

Organic Waste Systems






OWS N.V.

Dok Noord 4
B-9000 Gent
Belgium
Tel. (+32)-9-2330204
Fax (+32)-9-2332825
e-mail: mail@ows.be
http://www.ows.be

OWS Inc.

3155 Research Boulevard
Suite 104
Dayton, Ohio 45420
USA
Tel. (+1)-937-253-6888
Fax (+1)-937-253-3455
e-mail: r.tillinger@worldnet.att.net

Organic Waste Systems

anaerobic digestion of organic waste

THE DRANCO TECHNOLOGY

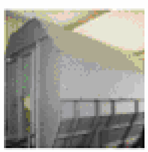
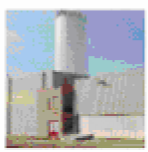
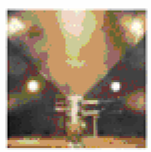
Environmentally friendly and cost-effective organic waste treatment by means of DRy ANaerobic COmposting (DRANCO)

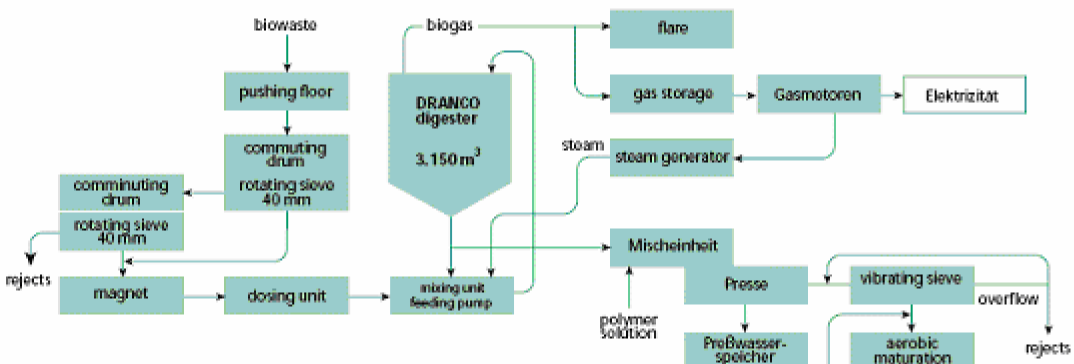
The DRANCO process characteristics

- thermophilic or mesophilic, one-phase anaerobic fermentation system
- high wastestream flexibility
- proven and stable high-rate digestion process
- simple and reliable digester design: low maintenance, low wear
- no mixing inside digester
- controlled external inoculation
- high biogas yield and biogas production
- minimum of odour
- reduced surface area required
- automated process control

The DRANCO feedstocks

- biowaste
- organic fraction of grey waste or mixed waste
- industrial organics
- paper waste
- market waste
- manure
- sewage sludge etc.

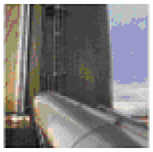





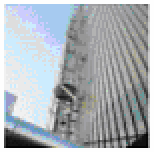


DRANCO plant Brecht, Belgium

DRANCO INSTALLATION REFERENCE LIST

City, country	Capacity (ton/year)	Waste	Year
Full-scale plants			
Brecht I, Belgium	20.000	Biowaste / wastepaper	1992
Salzburg, Austria	20.000	Biowaste	1993
Bassum, Germany	13.500	Grey waste	1997
Aarberg, Switzerland	11.000	Biowaste	1998
Kaiserslautern, Germany	20.000	Grey waste	1999
Villeneuve, Switzerland	10.000	Biowaste	1999
Brecht II, Belgium	50.000	Biowaste / wastepaper	2000
Alicante, Spain	30.000	Mixed waste	2002
Rome, Italy	40.000	Mixed waste	2002
Demonstration plants			
Gent, Belgium		Mixed waste / biowaste	1984
Bogor, Indonesia		Market waste	1986
Florida, USA		Mixed waste	1989
Graz, Austria		Mixed waste	1990
Kagoshima, Japan		Manure /organic waste	1998
Yaku Island, Japan		Manure /organic waste	2001





THE SORDISEP TECHNOLOGY

SORting, DIgestion and SEParation (SORDISEP) of municipal and industrial waste for the recovery of recyclables and the production of energy by means of the DRANCO digestion process. Wet separation is performed after digestion.

Scheme consisting of dry sorting, anaerobic digestion and wet separation

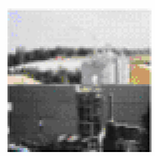
- recovery of a high-calorific fraction, Refuse Derived Fuel (RDF), ferrous and non-ferrous metals in the dry sorting step
- production of biogas from the low-calorific organic fraction during the DRANCO anaerobic digestion step
- recovery of sand, fibres and inerts for recycling in the wet separation step after the anaerobic digestion

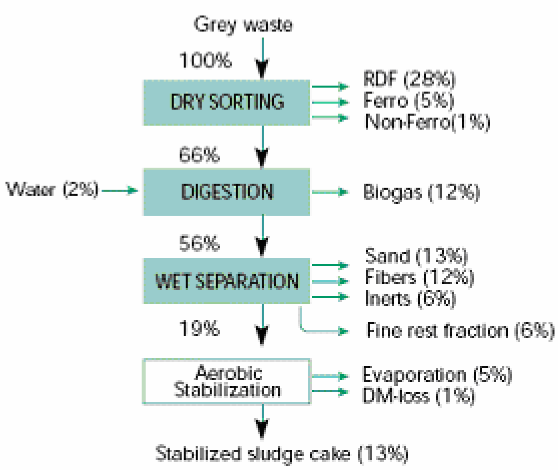
The SORDISEP process combines the advantages of dry digestion and wet separation.
The digestion first removes sticky and odorous components, as well as easily degradable organics and cellulose.

Advantages of digestion followed by wet separation:

- easy release of recyclable components (sand, inerts,...)
- tecovery of fibres made possible
- maximum recovery and high purity of recyclable fractions
- no wastewater production
- minimal odour generation
- homogeneous mixture of digested residue to wet separation phase=high flexibility towards waste input

The SORDISEP process combines maximum recovery of recyclables and energy recovery and a minimization of landfilling.



Organic Waste Systems

BUDGETARY OFFER
DRANCO PLANT FOR
25.000 TONNES OF BIOWASTE

For: Danielle Sorenson
Date: April-07-2006

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2. THE DRANCO PROCESS

The DRANCO digestion technology is a waste treatment technique which degrades and stabilizes organic material. The technique is ideal for waste streams containing a lot of organic material such as biowaste (kitchen and garden waste), grey waste, dewatered sludge, organic industrial waste among others.
The waste degradation takes places in the absence of oxygen, e.g. under anaerobic conditions, by means of bacteria. The degradable waste fraction is converted into biogas, a mixture of methane and carbon dioxide. Biogas is a renewable source of energy to be used for the production of electricity, heat, steam or, after recycling, as fuel. The non-degradable fraction forms a residue having a total solids content depending on the input material. The residue has to be treated further depending on the input material. Residue from grey waste or equivalent waste can, after stabilisation, be landfilled or incinerated or go through a wet separation to recover a maximum of recyclable fractions. Residue from biowaste or equivalent waste can, after dewatering and further stabilisation, be commercialised as a high-quality compost.

Characteristics:

- The DRANCO process is a one-step digestion process. The different digestion process steps take place in the same reactor volume. As a result the construction of the installation is simpler in comparison with multiple-step digestion technologies, which increases operational reliability.

- The digestion occurs by means of thermophilic bacteria, which operate in a temperature area between 48 and 55°C. Most pathogens are killed in the reactor by the high temperature and the anaerobic conditions.

- The mixing of fresh waste with excess residue, i.e. already digested waste, takes place outside the DRANCO reactor. The patented system permits an excellent control of the mixing and makes it possible that inside the reactor no mixing or stirring system is necessary. This results in a simpler reactor construction, which leads to a long, reliable and free of interference operational management of the installation.
  The high relation of residue to fresh waste during mixing leads to a quick degradation, which starts immediately after the introduction in the reactor. Because of this sudden fluctuations in the composition of the supplied waste are met without problems.

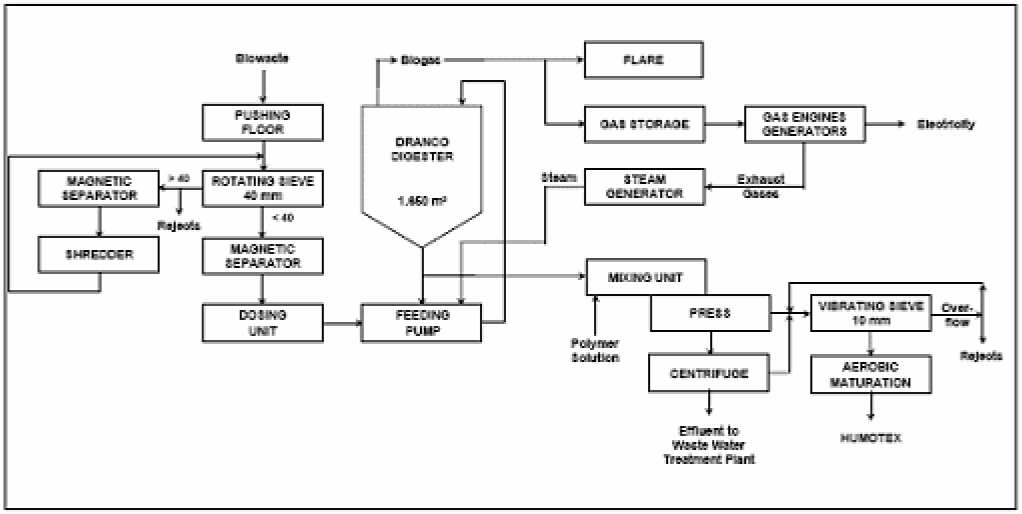
- The DRANCO process takes place in standing reactors. A rugged solid pump introduces the mixture in the upper part of the reactor. By means of gravity the material then moves downwards. Extraction screws placed outside the reactor remove the residue.

- The DRANCO technology permits to treat various waste streams with the same reactor type: from wet to very dry waste streams. The DRANCO process is a semi-dry to very dry digestion process and is operational till 40% TS-content in the reactor. In practice the reactor is operated at a TS-content which is spontaneously adjusted depending on the kind of waste. By keeping the TS-content in the reactor high, sedimentation and flotation problems are avoided to a great extent. This means that floating materials such as woody material, polystyrene foam, plastics among others cannot form a crust, while heavy elements, such as sand and other inerts, cannot deposit.

2. DESCRIPTION OF THE INSTALLATION

2.1. Introduction

The installation is designed to treat 25.000 tonnes of biowaste per year and is operated during 1 shift a day (8 hours/day), 250 days a year.



2.2. Pretreatment

The biowaste is brought on a pushing floor which transports the waste to a rotating sieve. The overflow of the sieve (> 40 mm) is transported to a shredder, which reduces the waste. The shredded waste is brought back into the rotating sieve. The fraction < 40 mm is transported into a dosing unit.

2.3. Anaerobic digestion

The dosing unit functions as a buffer between the pre-treatment and the proper digestion. The unit doses the waste to the feeding pump, which feeds the digester. Above the feeding pump, a mixing unit is placed where the fresh organic waste is mixed with residue, already digested waste coming from the digester and functioning as inoculum, with the purpose to start-up the anaerobic digestion as quick and smooth as possible. In the mixing unit a small amount of low-pressure steam is injected to heat up the mass till a temperature of 48-55°C. Subsequently the mass is pumped to the top of the digester where it is brought in the digester. There an intensive anaerobic digestion takes place by a dry solids content between 15 and 40% and a temperature between 48 and 55°C. The digester itself is a vertical cylindrical reactor with a conical outlet, made of steel and insulated to reduce heat losses. There is no mixing equipment inside the digester. The fermenting mass moves from top to bottom through gravity. To handle the given amount one digester of 1.650 m³ is needed. The average retention time in the digester is about 25 days. The residue leaves the digester through the conical outlet and is recycled to the feeding pump to serve as inoculum. A part of the residue is sent towards the dewatering unit.

2.4. Biogas treatment

During the fermentation phase approximately 70% of the volatile solids introduced in the digester is converted into biogas. The biogas collected in the digester flows under normal conditions, through difference in pressure, out of the digester towards the gas storage. From here the biogas is sent to the biogas engines. When biogas production exceeds consumption or in cases of emergency, the biogas can be burnt by means of a flare.

2.5. Dewatering of the residue

A part of the residue is brought to the dewatering unit. In the mixing unit the residue is at first intensively mixed with a polymer solution, prepared in the flocculant unit. Adding flocculants to the residue before pressing increases the degree of dewatering and, at the same time, the quality of the press liquid. It also leads to a stable functioning of the press. The mixing takes place in batch: the residue and polymer solution is brought into the mixing unit, mixed and subsequently released into the hopper of the underlying dosing screw which brings the mixture into the screw press. In the press the residue is dewatered till a dry solids content between 45 and 50%. The press cake is subsequently transported to a sieve (10 mm). The fraction smaller than 10 mm is transported to the aerobic maturation hall. The fraction > 10 mm will go to a container. The press water is collected under the press and sent to the centrifuge, where the sludge is removed. At the entrance of the centrifuge the press water can be flocculated with a polymer solution if necessary. The effluent of the centrifuge is collected and needs to be sent to a water treatment unit. To counteract the forming of foam on the effluent, an anti-foam product can be added. The centrifuge cake comes together with press cake and is brought to the aerobic maturation hall.

2.6. Aerobic maturation

The press and centrifuge cake can easily be aerobically post-composted without addition of any structural material. The material is fully automatically spread out in rows, which at the end form a heap with a uniform height of about 2,5 m. A controllable air flow is blown through the heap via grooves in the bottom plate. After a retention time of about 14 days the compost is matured.

3. SPECIFICATIONS OF THE INSTALLATION

3.1. Capacity

The installation has a capacity of 25.000 tonnes of biowaste per year. This results in a weekly capacity of 500 tonnes or 100 tonnes per day, calculating with 50 weeks and 5 days a week.
The biowaste has a total solids content of 35%, a volatile solids content of 65% and a biodegradability of 70%.

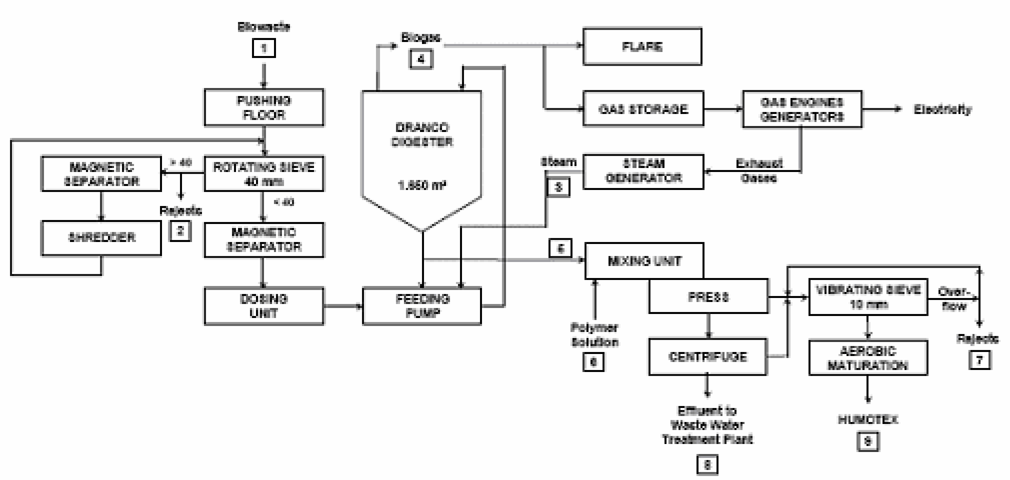
3.2. Operating hours

The installation is operated during 1 shift per day and 5 days per week. The gas production takes place on a continuous basis.

3.3. Operating staff

Three persons per shift are to be foreseen for normal operation and maintenance of the entire installation.

3.4. Mass balance



	1	2	3	4	5	6	7	8	9
T/Y	25.000	1.260	476	4.200	20.025	1.680	1.000	10.725	8.300

3.5. Consumables

- Electricity consumption: the installed power of the DRANCO installation is about 1.000 kW and the consumption is about 1.500.000 kWh per year.
- Polymer powder: the consumption of polymer powder per tonne residue amounts to 1 kg, resulting in about 20 tonnes per year. The budgetary cost is about € 3,00 per kg.
- Anti-foam: the total amount is about 2.000 litres per year at a budgetary cost of € 2,65 per kg.
- Potable water for the process is only needed in the floculant unit and the steam generator. The consumption is about 1.975 m³ per year.

3.6. Biogas production

The biogas production is 125 Nm³/ton waste going to the reactor or 339 Nm³/h. This results in a production of 2.968.750 Nm³ per year.

Estimation of the average biogas composition:

CH_4 content	55%
H_2S content	300 ppm
Heating value	19,45 MJ/Nm³
Relative humidity	100%

3.7. Waste water characteristics

Estimation of the average waste water composition after the centrifuge:

Conductivity	24.000 µS/cm
COD	35.000 mg/l
BOD5	17.500 mg/l
Kj-N	3.600 mg/l
NH_4-N	1.900 mg/l
Norg-N	1.700 mg/l

3.8. Electricity production

In the offer two power units of each 469 kWel are provided. The total production amounts to 5.250.000 kWh per year.

4. ECONOMICAL DATA

4.1. Scope of supply

The budgetary price for the electro-mechanical part includes:

- Engineering, transport, delivery, mounting and start-up of:
  - 1 pushing floor
  - 1 rotating sieve
  - 1 shredder
  - 2 magnetic separators
  - 1 dosing unit
  - 1 feeding pump
  - 1 DRANCO digester
  - 1 mixing unit
  - 1 screw press and 1 press water pump
  - 1 centrifuge
  - 1 anti-foam unit
  - 1 flocculant unit with 2 polymer dosing pumps
  - 1 vibrating sieve
  - 1 gas storage with water lock
  - 1 flare
  - 1 steam generator
  - 2 power units
  - screws
  - belt conveyors
  - chain conveyor
  - hydraulic and pneumatic group for valves
  - necessary piping (for the residue, biogas, press water, polymer solution, anti-foam, potable water, hydraulic oil and pneumatic air)
  - necessary instrumentation and valves on the equipment and piping
  - necessary supporting structures and walking floors
  - cable work for power supply and instrumentation
  - electrical cabins
  - air treatment
  - automation with control station.

- Supervision of OWS at the site during start-up of the installation and a one month period of performing tests.

The budgetary price for the civil engineering includes:

- Buildings
- Foundations.

Not included in the supply:

- Waste water treatment

- Spare and wear parts
- Obtaining of the necessary permissions for the construction and/or operation of the plant (assistance included)
- Personnel and consumables (electricity, water, ..) for the operation of the plant during start-up (supervision included).

4.2. Budgetary investment price

	Price, without VAT
Electro-mechanical part:	€ 11.000.000,00
Civil engineering:	€ 2.000.000,00
Total budgetary investment price:	**€ 13.000.000,00**

4.3. Budgetary operating cost

• Annuity:	
• EM-part: period: 15 years & interest: 7%	€ 1.207.741,00
• Civil eng.: period: 20 years & interest: 7%	€ 188.786,00
• Costs for personnel:	
• 4 persons at € 40.000,- per year	€ 160.000,00
• Costs for consumables:	
• Oils & fats, polymer, anti-foam & potable water, analyses	€ 100.000,00
• Maintenance (incl. spare parts):	
• EM-part: 3% of the investment per year	€ 330.000,00
• Civil eng.: 1% of the investment per year	€ 20.000,00
• Insurances & admin. costs:	
• 0,5% of the investment per year	€ 65.000,00
Total operating cost:	**€ 2.071.527,00**

Remark: Some smaller costs have not been taken into account. Also the revenues of the electricity and compost have not been taken into account.

Overview of budgetary costs and energy production for DRANCO plants treating waste (prices in Euro)

Parameter	Unit	Capacity				
		5.000 t/y	10.000 t/y	25.000 t/y	50.000 t/y	100.000 t/y
Investment price	Mio. Euro	9	12	15	20	30
Operating costs	Euro/ton	40	30	25	20	15
Surface area	m^2	3000	4000	7000	10000	15000
Electricity production	kWh/t	225	225	225	225	225
Surplus of electricity	kWh/t	140	140	145	150	150
Heat production	kWh/t	300	300	300	300	300
Surplus of heat	kWh/t	270	270	270	270	270

The civil engineering is included in the investment price, but not the acquisition of the land.
The amortization of the investment is not included in the operating costs.